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SOIL-SALINITY STUDIES AS RELATED TO SUGARCANE GROWING IN SOUTHWESTERN PUERTO RICO[1]

Juan A Bonnet[2]

INTRODUCTION

A multiple-purpose project covering hydroelectric power, irrigation, drainage, and water supply, is being worked out for Lajas valley in the arid southwestern section of Puerto Rico. The estimated total cost of the project is $26,789,000 and water is expected to flow at the end of 1953 to begin the irrigation of about 24,000 acres in the valley, largely to be planted to sugarcane.

There are about 10,000 acres of additional land in Lajas valley where salinity problems affect the growth of sugarcane. This paper discusses such problems on the basis of surveys and experiments made by the author and his coworkers (2, 3)[3] before the irrigation works were started.

DEFINITIONS AND METHODS

The terms used in this report (table 1) are those adopted by the U. S. Regional Salinity Laboratory (6). "Saline" refers to the presence of excess salts and "alkali" as related to excessive exchangeable sodium. Nonsaline-alkaline soils are those found occasionally that contain exchangeable sodium, except for the soluble salts which have been removed by leaching. Saline-alkaline soils probably constitute the majority found containing excesses of both exchangeable sodium and soluble salts.

The "saturation extract" (6) reported in the second column of table 1 is a solution obtained by pressure or vacuum filtration of a soil paste that has been made up to a saturated condition by adding water while stirring. The electrical conductivity in that column is expressed as EC $\times$ 10^3 in millimhos/cm.

Adequately spaced soil samples were taken throughout the whole area of Lajas valley, using an auger at 1-, 2-, 3-, and 4-foot depths. The samples

[1] Paper prepared for the Eighth Congress of the International Society of Sugarcane Technologists at Barbados, B. W. I., in April 1953.

[2] Head, Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[3] Numbers in parentheses refer to Literature Cited, p. 113.

were dried overnight in an oven kept around 60°C. The dry samples were ground by hand power in a corn mill No. 2. A 1:2 soil-water suspension was prepared by adding 80 ml. of distilled water to 40 gm. of soils in a 250-ml. beaker.

The suspensions were preferred to the saturation extracts because the preparation is simpler and quicker. Twelve suspensions were shaken for 30 minutes in a Ross-Kershaw stirring apparatus (No. 9235-D, A. H. Thomas Catalog) at about 185 revolutions per minute. Each suspension was poured into a 100-ml. test tube, 1.25 inch in diameter, and the conductivity value was determined with a Solu-bridge soil tester, model RD-15, using a heat-resistant rubber cell-4 with a constant value of 2.0. The scale markings in this Solu-bridge are expressed as specific electrical con-

TABLE 1.—*Classification of saline and alkali soils used by the U. S. Regional Salinity Laboratory (6)*

Soil class	Electrical conductivity of saturation extract in millimhos/cm.	Exchangeable Na as percentage ESP[1]	pH
Saline	4 or higher	Less than 15	Usually less than 8.5
Saline-alkali	4 or higher	15 or higher	Seldom higher than 8.5
Nonsaline-alkali	Less than 4.0	15 or higher	Usually greater than 8.5
Soloth or degrated	Less than 4.0	15 or higher	Usually between 6.5 and 8.0 but may be below 6.0

[1] $\text{ESP} = \dfrac{\text{Exchangeable sodium (m.e. per 100 gm. soil)}}{\text{Cation exchange capacity (m.e. per 100 gm. soil)}} \times 100.$

ductance or electrical conductivities, EC in mhos/cm. $\times 10^{-5}$ at 25°C. This value is equivalent to EC $\times 10^{-5}$ or K $\times 10^{5}$, used by the U. S. Regional Salinity Laboratory (6).

THE PROBLEM AND ITS SOLUTION

Quality of the Irrigation Water Supplies

The scale used to classify the water supplies with respect to their irrigation quality is reported in table 2.

Twenty-nine water samples supplied from wells used for irrigation, including two lagoons in Lajas valley, were analyzed and seven were found to be excellent to good for the irrigation of crops. Waters from seven rivers (2) that supply the reservoirs for the irrigation waters were also analyzed and found excellent to good. One of these rivers, the Río Loco, that has been used in the past for irrigation in Lajas valley, flows through a serpentine region and contains 26 p.p.m. in flood, and 41 p.p.m. of magnesium

in normal flow, or from three to six times more magnesium than the other river waters.

The Salinity Problem

There is no danger of the intrusion of sea water through the south of the valley, since there is no direct connection through permeable rocks between the valley fill and the sea along the entire south of the valley.

The salinity problem of Lajas valley has developed by seepage caused by impeded drainage, and by surface-soil evaporation because of the salts from the salty wells used for irrigation and the run-off drain toward the lowlands. By this process the salt content of the ground water has been increased and salt flats have been formed, of which the low terrain known as the "Ciénaga el Anegado," comprising 1,931 acres, is typical. These

TABLE 2.—*Standards for judging the quality of irrigation waters (4, 6)*

Water class No.	Water condition	Electrical conductivity in millimhos/cm.	Salt content—		Sodium	Boron
			Total	Per acre-foot		
			P.p.m.	*Tons*	*Percent total bases*	*P.p.m.*
1	Excellent to good	1	0–700	1	Below 60	Below 1
2	Good to injurious	1–3	700–2,000	1–3	60–75	1–2
3	Injurious to unsatisfactory	3+	Over 2,000	Over 3	Over 75	Over 2

salt flats are distributed sporadically, in an irregular pattern, in Lajas valley, and even the bottom soils of the two fresh-water lagoons, the Guánica lagoon with about 1,123 acres and the Cartagena lagoon with about 251 acres, are also salty.

Rainfall and Evaporation

The mean annual rainfall of Lajas valley is 31.35 inches. The drier period extends from December to April with a mean total rainfall of 6.82 inches; January is the driest month with 0.84 inch.

The mean monthly evaporation from a free water surface in the Lajas Agricultural Experiment Substation was 7.72 inches for the 6-month period, February to July 1949, and 11.23 inches for the 9-month period, July 1951 to March 1952. The monthly range for the 1949 records was from 6.04 to 8.87 inches and for the 1951–52 records, from 8.09 to 16.15 inches. There were 55 days with no evaporation for the latter period; the highest daily evaporation was 1.20 inches on December 9.

The Leaching Tests

Three leaching tests (3) with fresh waters were made in salty spots of Aguirre clay. This soil occurs in the low flat areas of Lajas valley. It occupies areas that are transitional in character between the soil of the well-drained river flood plains or alluvial fans and the poorly drained soils of the coastal lowlands. In a cultivated field, Aguirre clay has a 10- or 12-inch layer of very dark grayish-brown or nearly black plastic clay underlain by mottled grayish-brown and gray plastic clay that continues to a depth ranging from 30 to 36 inches. At a depth ranging from 5 to 6 feet is the substratum of bluish-gray plastic, sticky, wet clay. This layer continues to considerable depths and has the characteristics of estuarine deposits. Many areas are affected by salts. The best-drained areas that receive some irrigation are producing from 40 to 60 tons of Gran Cultura cane to the acre. The land is difficult to plow and cultivate, as it is plastic and sticky when wet and hard and cloddy when dry. There are about 7,881 acres of Aguirre clay, in Lajas valley.

Half an acre of land was divided into 24 plots, each 10 feet x 10 feet, separated crosswise and lengthwise by ditches 4 feet deep. Twelve randomized plots that were irrigated with fresh water were protected with bamboo canes to avoid landslide. In the third leaching tests, all the plots were irrigated; half of the randomized plots received sulfur at the rate of 8 pounds per plot, or 1.74 tons per acre. Half of these plots received the sulfur in one application and the other half at the same rate, but in four weekly applications.

In the first leaching test five separate soil samples were taken from each irrigated plot, one each at 1-, 2-, 3-, and 4-foot depths, and in the second and third tests they were taken at more convenient depths with the soil auger, at 8, 16, 24, 32, 40, and 48 inches, to be used for conductivity tests.

The first and second leaching tests lasted 73 and 63 days, and were leached with 78 and 84 inches of water, respectively. The third test lasted 130 days; the plots to which the sulfur was added in four applications and in one application were leached with 48 and 60 inches of water, respectively, and the untreated plots with 72 inches of water.

The three leaching tests revealed that irrigation with 48 inches of water washed out the excess of salts from the first foot of soil if adequate drainage was provided.

The Salty Land of Lajas Valley

The salty land was largely of two soil types, Aguirre clay and Guánica clay. There are about 4,518 acres of Guánica clay in Lajas valley. Guánica clay is similar to Aguirre clay, but it is more poorly drained and therefore is less well aerated and oxidized. It occupies lower positions than does

Aguirre clay, and it is more difficult to drain and to irrigate. The largest areas of Guánica clay occupy lagoonlike positions near Guánica Lagoon that have been filled with materials washed from the nearby hillsides, and consisting of tuffaceous rock and limestone. Only a small portion of this soil is irrigated with well water. Some of the water has a fairly high salt content. Unless the land is irrigated, the productivity depends to a very large extent on the yearly rainfall. An acre-yield of 40 tons of Gran Cultura cane is considered high on nonirrigated land, but in the irrigated areas yields ranging from 50 to 60 tons are not uncommon. This soil also requires good drainage. It is a good soil for rice.

The area of salty land that could be reclaimed with fresh waters, if good drainage is provided, based on the results obtained with the leaching tests, was found to be about 5,453 acres. The additional area of salty land that could be reclaimed with sulfur or gypsum and fresh waters, if good drainage is provided, was found to be about 5,028 acres.

A total of 6,822 soil samples were taken for conductivity tests at the 1-, 2-, 3-, and 4-foot depths, from 1,955 borings adequately spaced in the fields. The mean conductivities in the 1:2 soil-water suspensions for 1-foot layer of the salty lands planted to sugarcane varied from 8 to 320 mhos $\times 10^{-5}$ at 25°C. and for the upper 4-foot layer, from 10 to 400 mhos. The mean values for the uncropped land in range pastures varied from 10 to 1,000 mhos $\times 10^{-5}$ at 25°C. in the 1-foot layer and from 6 to 1,000 mhos $\times 10^{-5}$ at 25°C. in the 4-foot layer.

Chemical Data from the Salty Land

The cation-exchange capacity, and cations extractable with normal ammonium acetate, for 15 soil samples representing salty Aguirre clay and Guánica clay and nonsalty Fraternidad clay, Santa Isabel clay, Vayas silt loam, and San Antón clay loam, are reported in table 3.

The cation-exchange capacity of these soils varied from 28.0 to 60.3 milliequivalents per 100 gm. The extractable cations varied from 21.6 to 74.0 m.e. for Ca, from 0.14 to 0.41 m.e. for Mg, from 0.08 to 1.08 m.e. for Mn, from 1.4 to 26.7 m.e. for Na, and from 0.27 to 1.28 m.e. for K, per 100 gm. of soil.

The total cation-exchange capacity in six of the soils analyzed was saturated with calcium, and the remainder of the Ca, Mg, Mn, Na, and K extractable cations were combined as free salts. These salts, especially the harmful sodium salts, are leached out with fresh waters if good drainage is provided. This was corroborated in the three leaching tests, reported earlier where irrigation with fresh water washed out the excess of salts from the soil when adequate drainage was provided.

In the other nine soils analyzed, the extractable cations were exchange-

TABLE 3.—*Cation-exchange capacity and extractable cations*[1] *in soils of Lajas valley*

Lab. No.	Soil type and cover	Location	Cation-exchange capacity	Extractable cations in milli-equivalents per 100 gm. soil, of—				
				Ca	Mg	Mn	Na	K
140	Aguirre clay (0–36″), cane grows well	Hacienda Luz Dolores, Juan Angel Tió, Lajas	43.8	74.0	0.41	0.52	5.0	0.27
141	Aguirre clay (0–36″)—poor spot—cane does not grow well	A short distance N.E. sample 140	28.0	62.3	.41	.24	20.4	.84
143	Aguirre clay (0–30″)—trees	Antonio Matos farm, S.E. Anegado, Lajas-Guánica road	60.2	61.3	.31	.56	25.0	1.28
144	Aguirre clay (30–48″)—trees	do.	58.2	33.3	.16	.22	26.7	1.08
149	Aguirre clay (0–12″)—to be planted to cane	Recent plowed field, 250 m. W. Hda. Beatriz Soledad, Mario Mercado, Lajas	50.4	35.1	.14	.08	3.8	1.06
150	Aguirre clay (0–12″)—cane does not grow well	Recent plowed field, 500 m. S. Hda. Beatriz Soledad	45.0	27.4	.31	.64	9.0	.62
151	Aguirre clay (12–36″)—cane does not grow well	do.	45.8	24.0	.15	.12	9.5	.79
152	Aguirre clay (0–12″)—to be planted to cane	Plow working in field 2 Km. S. houses Hda. Beatriz Soledad	60.3	48.3	.15	.08	11.0	1.16
153	Do.	Plow working, 1 Km. E. Hda. Beatriz Soledad houses at Luis Irizarry's farm	54.4	48.8	.27	.24	4.5	.59
154	Aguirre clay (12–36″)—to be planted to cane	do.	48.2	51.9	.38	.28	8.3	.51
142	Fraternidad clay (0–24″)—pastures	Km. 11.9 bend, Lajas-Guánica road, Juan Angel Tió's farm	32.8	37.4	.15	.10	4.9	.72
146	Guánica clay (0–12″)	West Guánica lagoon	36.0	51.4	.15	.12	6.8	1.04
139	Santa Isabel clay (0–12″)—good cane soil	Hda. María Luisa. Padres Mercedarios, Bo. Palmarejo, Lajas	41.6	30.0	.16	.06	2.5	.43
147	Vayas silt loam (0–36″)—good cane soil	E. Guánica lagoon near outlet ditch to ocean, farm of Alfredo Ramírez	46.0	36.3	.51	1.08	2.9	.32
148	San Antón clay loam (0–30″)—good cane soil	1.5 Km. S.E. Guánica lagoon, Hda. María Antonia, Rusell & Co.; good cane soil, planted for over 40 years	31.4	21.6	.15	.08	1.4	.50

[1] Cations extracted with normal ammonium acetate (6).

able cations. Among these, in sample No. 144, the total exchange capacity of the soil was occupied by the exchangeable cations. This sample had an excessive amount of extractable or exchangeable sodium, 26.7 m.e. Na

TABLE 4.—*Available boron*[1], *sodium chloride, extractable sodium*[2], *calcium-sodium ratios, pH, electrical conductivities, and presence or absence of free carbonates in soils of Lajas valley reported in table 3*

Lab. No.	B	NaCl in soil	Extractable sodium	Ca/Na	pH	EC[3]	Free carbonates
	P.p.m.	*Percent*	*Percent*				
140	0.55	0.29	11.4	14.8	9.0	55	Yes
141	2.00	1.19	72.9	3.1	9.2	278	Yes
143	2.70	1.46	41.5	3.5	8.3	400	Yes
144	1.55	1.56	45.9	1.2	8.2	650	Yes
149	1.05	.22	7.5	9.2	7.7	60	No
150	.75	.53	20.0	3.0	8.3	108	No
151	1.00	.56	20.7	2.5	8.4	148	Yes
152	1.80	.64	18.6	4.4	8.1	370	Yes
153	.75	.26	8.3	10.8	7.7	100	No
154	1.00	.49	17.2	6.3	8.4	160	Yes
142	.55	.29	14.9	7.6	8.8	52	Yes
146	1.30	.40	18.7	7.6	8.9	50	Yes
139	.55	.15	6.0	12.0	7.5	36	No
147	1.30	.16	6.3	19.4	8.5	43	Yes
148	1.30	.08	4.5	15.4	8.1	34	No

[1] Available boron dissolved in boiling water (1).

[2] Extractable sodium percent $= \frac{\text{Extractable Na}}{\text{Cation Exchange Capacity}} \times 100.$

[3] Mhos. $\times 10^{-5}$ at 25°C. in 1:2 soil-water suspension.

TABLE 5.—*Range of available boron, sodium chloride, extractable sodium, calcium-sodium ratios, pH, and electrical conductivities in good and poor cane soils in Lajas valley*

Soil rating	Samples Nos.	B	NaCl in soil	Extractable Na	Ca/Na	pH	EC[1]
		P.p.m.	*Percent*	*Percent*			
Good	140, 139, 147, 148	0.55–1.30	0.08–0.29	4.5–11.4	12.0–19.4	7.5–9.0	34–55
Poor	141, 150, 151	.75–2.00	.53–1.19	20.0–72.9	2.5–3.1	8.3–9.2	148–370

[1] Mhos. $\times 10^{-5}$ at 25°C. in 1:2 soil-water suspension.

per 100 gms., that could not be leached out with fresh water only. Such chemicals as gypsum or sulfur, would be required in excess, besides fresh water and good drainage. The reclamation of excessive salty land under these conditions is not economical. The other samples (Nos. 149, 150,

151, 153, 146) of salty land in this group contained between 3.8 and 9.5 m.e. of extractable or exchangeable sodium per 100 gms. Under these conditions salty land may be reclaimed economically with chemicals. Soil sample No. 151 that contained 9.5 m.e., or 20.7 percent of exchangeable sodium, would require about 4 tons of gypsum per acre—6″ to reduce the exchangeable sodium one-half (6, p. 57).

The available boron in the soils of Lajas valley varied from 0.55 to 2.70 p.p.m. B, the sodium chloride from 0.08 to 1.56 percent, the extractable sodium from 4.5 to 72.9 percent, the calcium-sodium ratio from 1.2 to 19.4, the pH from 7.5 to 9.2, the conductivities of 1:2 soil-water suspensions from 34 to 650 mhos $\times 10^{-5}$ at 25°C., and 10 of the soils gave positive tests for free carbonates (table 4). In table 4 the salt content is expressed in terms of electrical conductivity, as EC in mhos $\times 10^{-5}$ at 25°C. The U. S. Regional Salinity Laboratory (table 1) expresses EC in terms of millimhos/cm. for a saturation extract consisting of a solution obtained by pressure or vacuum filtration of a soil paste that has been saturated by adding water while stirring.

The salty soils of Aguirre clay where sugarcane grew poorly (table 5) contained from 0.75 to 2.00 p.p.m. of available boron, from 0.53 to 1.19 percent of sodium chloride, from 20.0 to 72.9 percent of extractable sodium, from 2.5 to 3.1 in calcium-sodium ratios, and from pH 8.3 to pH 9.2.

Soil Drainage and the Infiltration Rate of the Salty Land

The Lajas valley project must be carried out under an efficiently controlled irrigation-drainage system.

Infiltration is the rate at which water enters the soil surface. Twenty-four quadruplicate tests (3) were performed on nine soil types of Lajas valley, including the salty Aguirre clay. The buffer-compartment method of Nelson and Muckenhirn (5) with three concentric rings, 9, 18, and 27 inches, respectively in diameter, 5 inches high, and a 2,000 ml. burette water reservoir was used. The test was run for eight consecutive hours and records were kept for every hour.

The maximum infiltration rate was obtained for all soils in the first hour, because they were dry and absorbed more water. From the second hour on the infiltration rate was reduced until the eighth hour, when the minimum was obtained. Salty Aguirre clay had very slow to slow minimum infiltration rates varying from 0.03 to 0.08 inch per hour.

Reclamation with Chemicals

A tract of high salty Aguirre clay with specific conductances in a 1:2 soil-water suspension varying from 186 to 445 mhos $\times 10^{-5}$ at 25°C., was chosen for the reclamation field experiment (2) with gypsum and sulfur.

Twenty square plots, each 20 feet x 20 feet, were separated by a ditch 2-feet wide followed by a pathway 5 feet wide and a second ditch. The plots were grouped into five blocks and each block was subdivided into four plots for the following randomized treatments: Check, leached, sulfur, gypsum.

Sulfur and gypsum were applied at rates of 1 and 2 tons per acre, respectively. The chemicals were hoed and mixed well with the surface soil. The plots were planted on January 19, 1948, with cane variety POJ 2878 and immediately irrigated by filling the furrows to the top with fresh water. The water was kept in the furrow by plugging its end with earth. The frequency of irrigation varied between 8 and 10 days until 1 month before harvest. Nitrogen as ammonium nitrate, at the rate of 283 lbs. of N per acre, was the only fertilizer applied. The crop was harvested at the age of 12½ months.

Discarding the results from two blocks affected by high water table and poor drainage at the drainage outlet, the data indicated that the gypsum treatment was significantly better than the check and leached treatments but that there were no significant differences between the sulfur, check, and leached treatments.

The cane juices from all treatments were salty, but were acid in reaction, around pH 5.7, and their mean specific conductance was found to be 697 mhos x 10^{-5} at 25°C., equivalent to an estimated 4,879 parts per million of soluble salts. Juices of 20 canes from nonsalty soils gave specific conductances, or electrical conductivities, ranging from 130 to 275 mhos $\times 10^{-5}$ at 25°C., equivalent to about 910 to 1,925 parts per million of salts, respectively. These good juices were slightly less acid, pH 5.8 to 6.0, than the ones from POJ 2878 cane grown in the highly salty land.

SUMMARY

The salinity problem of Lajas valley in southwestern Puerto Rico has developed from seepage caused by impeded drainage and by surface-soil evaporation because the salts from the salty wells used for irrigation and the run-off drain toward the lowlands. A project is under way in Lajas valley to irrigate about 24,000 acres of good cane land. Salts also affect adversely the growth of sugarcane on about 10,000 acres in addition.

The salty lands include saline, saline-alkali, and nonsaline alkaline soils. Saline soils contain excessive salts and alkaline soils contain excessive exchangeable sodium. The excess of salts in the saline and saline-alkali soils can be leached out by fresh water if good drainage is provided, as was shown by three leaching tests performed in the field. The excess of salts in the saline-alkali soils and the excess of sodium in the saline-alkali and nonsaline alkaline soils may be leached out with gypsum or sulfur

and fresh water, if good drainage is provided, and if the exchangeable sodium to be removed is not excessive, that is about 5 m.e. per 100 gms. of soil.

The high content of extractable or exchangeable calcium generally present in the salty lands of Lajas valley is a good asset for their successful reclamation with fresh water and chemicals such as gypsum or sulfur, if adequate drainage is provided. In a field test, an application of 2 tons of gypsum per acre produced a significant increase in cane yield, but the acid juice of the cane was salty.

Sugarcane grows poorly in the salty lands of Lajas valley that contain from 0.75 to 2.00 p.p.m. of available boron, from 0.53 to 1.19 percent of sodium chloride, from 20.0 to 72.9 percent of extractable sodium, from 2.5 to 3.1 calcium-sodium ratios, and the pH of which ranges 8.3 to 9.2. Good sugarcane growth was observed when the salty land contained 4.5 to 11.4 of extractable sodium and the calcium-sodium ratios were 12.0 to 19.4.

RESUMEN

El problema de la salinidad del Valle de Lajas, en la parte suroeste de Puerto Rico, ha sido el resultado del desagüe inadecuado y de la evaporación de las escorrentías del agua salada de los pozos, usada para el riego.

Estas aguas saladas han venido usandose, por muchos años, para regar la caña de azúcar en esta árida región. Toda la zona contiene alrededor de 10,000 acres de terrenos salados.

El sistema de riego del Valle de Lajas, actualmente en construcción, podrá proveer agua a 24,000 acres de terrenos fértiles.

Las tierras saladas de esta zona comprenden suelos salinos, salino-alcalinos y alcalinos no salinos.

Los suelos salinos contienen una cantidad excesiva de sales libres, mientras que los alcalinos tienen gran cantidad de sodio intercambiable.

Las sales libres en los terrenos se pueden lavar con agua de buena calidad, si el desagüe es adecuado. Esto quedó comprobado durante los experimentos que se llevaron a cabo en el campo.

Para eliminar el sodio intercambiable en los suelos alcalinos, es necesario, también, añadirles yeso o azufre. La adición de estos ingredientes resulta económica, cuando la cantidad de sodio intercambiable presente no exceda de 5 miliequivalentes, poco más o menos, por cada 100 gramos de suelo.

La presencia del calcio libre e intercambiable, en estos suelos salados, es abundante, y por lo tanto, favorable en cuanto a su eficaz reclamación.

En uno de los experimentos hechos, la aplicación de 2 toneladas de yeso por acre a un terreno salado, produjo un aumento significativo en el rendimiento de la caña de azúcar, pero los jugos resultaron salados.

Se observó que la caña creció pobremente en aquellas tierras saladas que

contenían de 0.75 a 2.00 partes por millón de boro asimilable; de 0.53 a 1.19 por ciento de cloruro sódico; de 20.0 a 72.9 por ciento de sodio; valores pH entre 8.3 y 9.2; y donde la razón entre el calcio y el sodio fluctuó de 2.5 a 3.1.

La caña de azúcar creció satisfactoriamente, cuando el terreno salado contenía de 4.5 a 11.4 por ciento de sodio y cuando la razón entre el calcio y el sodio fluctuó de 12.0 a 19.4.

LITERATURE CITED

1. Berger, K. C. and Truog, E., Boron tests and determination for soils and plants, *Soil Sc.* **57**(1) 25–36 1944.
2. Bonnet, J. A., Tirado-Sulsona, P., and Lugo-López, M. A., Attempt to reclaim with chemicals a salty clay in Puerto Rico, *J. Agr. Univ. P. R.* **33**(2) 75–84 1949.
3. Bonnet, J. A. and Tirado-Sulsona, P., Soil studies in Lajas valley; Agr. Expt. Sta. Univ. P. R. Bul. **86,** 64 pp., August 1950.
4. Hayward, H. E., Science in farming: The control of salinity, The Yearbook of Agriculture, 1943–47, pp. 547–53.
5. Nelson, L. B. and Muckenhirn, R. J., Field percolation rates of four Wisconsin soils having different drainage characteristics, *J. Am. Soc. Agron.* **33**(11) 1028–36 1941.
6. Richards, L. A., The diagnosis and improvement of saline and alkali soils, U. S. Regional Salinity Laboratory, Riverside, Calif., 157 pp., July 1947.

THE CONSTITUENT MINERALS OF SOME SOILS OF PUERTO RICO

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INTRODUCTION

The constituent minerals of soils are the mineral groups which make up the bulk of the inorganic portion. These inorganic materials make up approximately 95 percent of soils in general and contribute materially to their properties. The importance of these minerals has been emphasized (9)[2] for some time in a general way, but data on most soils, and particularly, on tropical soils are lacking.

The constituent minerals in soils are feldspar, quartz, mica, and clay-mineral groups. The properties of these minerals vary considerably within a group or series. In studying the minerals of soils, it is of importance to determine the type of mineral of the particular group or series being investigated, that is to say, what kind of feldspar, clay mineral, etc., occurs in any particular soil.

The variability of the soils of Puerto Rico has been discussed by Bonnet (4), Roberts (13), Thorp (14), and others, but a complete mineral study for only one soil, Catalina clay, has been reported by Bonnet (3).

COLLECTION OF SOIL AND ROCK SAMPLES

Studies on the mineral characteristics and mode of formation of tropical soils were initiated, in February 1943, at the former Institute of Tropical Agriculture at Mayaguez, P. R., by Bonnet, the first junior author, then Assistant Director and Chief Soils Technologist, of the Institute. In September 1944, the studies were continued by Bonnet in the Soils Department of the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras, under a cooperative agreement with the Institute. Dr. Jeffries visited the Institute for a 2-month period in 1943 and helped in the collection of the soil and rock samples throughout the Island of Puerto Rico and in the organization of the laboratory work carried later at the Experiment Station. The soils[3] were prepared for analysis at Río Piedras, and the sand, silt, and clay fractions together with the

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[2] Numbers in parentheses refer to Literature Cited, p. 139.

[3] Thanks are expressed to A. García-Porrata, Miss Socorro M. Gaztambide, Assistant Chemist, Institute of Tropical Agriculture, and F. Penne, Jr., assigned to do the laboratory work.

thin sections of the rocks, prepared by G. S. Rév of New York, were sent to Dr. Jeffries, at Pennsylvania State College, for mineral identification. Dr. Jeffries was appointed Visiting Soil Scientist of the University of Puerto Rico for the 3-month period between February 8 and May 4, 1950 and while at the Experiment Station studied the final data and reorganized it for publication.

SOILS STUDIED

With the idea of increasing knowledge of the mineral character of the tropical soils of Puerto Rico, profile samples were secured in 1943 of the principal soil series of Puerto Rico. Special care was exercised to select typical profiles and the Soil Survey of Puerto Rico (13) was used at all times in deciding the areas from which samples were obtained. Where possible samples of rock formations associated with the soils were obtained to be studied also if it appeared desirable. In all, 42 soil profiles were sampled which included 118 soil samples and 76 rock samples.

The soils considered in this report are described by Roberts (13) as deep upland soils (including some medium-deep soils here), shallow upland soils, inner plains soils, medium friable terraces and alluvial fans, compact soils of terraces and alluvial fans, compact coastal plains, friable coastal plains and very friable coastal plains, well-drained river flood plains and poorly drained river flood plains. These soils belong to the zonal, intrazonal and azonal orders.

Table 1 shows the soil series, the physiographic areas where they occur, and the locations at which the samples were secured; it includes 41 soil types of the 42 soil profiles sampled. In table 2 the soil types are classified as soil series according to soil groups (13).

METHODS OF ANALYSIS

The methods of analysis used in this study were petrographic and X-ray procedures especially adapted for soils (10, 12).

All samples were air-dried, screened to pass a 20-mesh screen using as little grinding as possible. Free iron oxides were removed using the nascent-hydrogen methods of Jeffries (6, 7). After the removal of the free iron oxides the samples were dispersed and separated in their sand, silt and clay fractions. The very fine sand fraction 0.10–0.05 mm., was examined petrographically using the methods discussed by Marshall and Jeffries (12). No heavy mineral separations were carried out, as this study was confined to the constituent mineral groups referred to previously. The very fine sand, silt, and clay fractions were studied by X-ray methods using the Geiger Counter X-ray spectrometer as described by Jeffries (8). The patterns obtained were compared with those of minerals of known

TABLE 1.—*Soil series studied, physiographic areas where they occur, and location of samples*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Aguilita clay	Upland shallow	4.7 Km. S. Boquerón Road	67°9.5′	17°58′
Aguirre clay	Flood and coastal plains, poorly drained	Colonia Fraternidad, Santa Rita, Ensenada	66°54.5′	18°1′
Alonso clay	Upland deep	Km. 34.7 Road 16, Yauco-Lares	66°51′	18°11.7′
Bayamón sandy clay	Coastal plains, friable	Side road to Hatillo, 0.7 Km. S.W. Arecibo-Lares Road	66°46′	18°26.6′
Cabo Rojo clay	Inner plains	Km. 2.4 Cabo Rojo, Puerto Real Road	67°10.5′	18°4.8′
Catalina stony clay	Upland deep	Km. 4.5 Mameyes-Yunque Road	65°46′	18°20.5′
Catalina clay	do.	Km. 9.6 Road 14, Consumo-Maricao	66°59′	18°11.5′
Cialitos clay, steep phase	do.	Km. 27.7 Road 14, Maricao-Indiera	66°54′	18°9′
Ciales clay loam	do.	Km. 41.6 Road 6, Adjuntas-Utuado	66°43′	18°13′
Coloso silty clay	Flood plains, poorly drained	1 Km. N.E. Central Eureka	67°7′	18°7.5′
Corozo fine sand	Coastal plains	Km. 75.0, Road 2 E. Arecibo	66°37.5′	18°27.5′
Coto clay, heavy phase	Coastal plains, friable	Km. 138.8, Road 2, Aguadilla-Isabela	67°7.5′	18°26.5′
Descalabrado silty clay	Upland shallow	Km. 217.5, Road 2, Sabana Grande-Yauco	66°57′	18°4′
Fraternidad clay	Terraces and alluvial fans	Colonia Marie Antonia, Santa Rita, Ensenada	66°54′	17°58′
Guánica clay	Flood plains, poorly drained	Balzac Faría farm, Colonia Limón, Guánica	66°56′	18°2′
Guayabo fine sand, shallow phase	Coastal plains	0.8 Km. S. Boquerón Road	67°9′	18°1.5′

TABLE 1.—*Continued*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Humacao clay loam	Terraces and alluvial fans, medium friable	Km. 85.0 Road 3, Humacao-Yabucoa	65°48.5′	18°8′
Islote loamy sand	Coastal plains	3 Km. W. Arecibo, Road 2	66°45.5′	18°28′
Jácana clay	Upland shallow	Km. 11.3 Road 18, Cabo Rojo, Boquerón	67°8.5′	18°3.5′
Juncos clay	Upland deep	Km. 7.9 Road 5, Caguas-Gurabo	65°58′	18°15.5′
Lares clay	Terraces, medium friable	Km. 5.8 Road 8, Moca-San Sebastián	67°6.5′	18°23′
Las Piedras clay loam	Inner plain	Km. 23.7 Road 5, Las Piedras-Humacao	65°52′	18°11′
Los Guineos clay	Upland, deep	Km. 13.6 Mameyes-Yunque Road	65°47′	18°18.5′
Mabí clay	Inner plain	4 Km. E. Cabo Rojo, Road 29, Cabo Rojo-San Germán	67°6′	18°5.5′
Maleza loamy sand	Coastal plains, very friable	4 Km. N. Cabo Rojo, Lighthouse	67°12′	17°57′
Matanzas clay	do.	Entrance Camp Borinquen, 0.3 Km. from Road 2	67°8.5′	18°27′
Moca clay	Inner plain	Km. 151.1 Road 2, E. Aguada	67°11′	18°23.5′
Múcara silty clay loam	Upland, deep	Barrio Llanos Tuna, 1 Km. E. of Km. 11.3 Road 18, Cabo Rojo-Boquerón	67°8′	18°3′
Nipe clay	Upland, deep	Km. 10, Mayaguez-Joyuda Road	67°11′	18°9′
Pandura sandy clay loam	do.	Km. 16 Road 5, Juncos-Las Piedras	66°54′	18°12.5′
Paso Seco silty clay	Terraces and alluvial fans	Hacienda Verdaguer of Central Aguirre, Guayama	66°7′	17°57′

TABLE 1.—*Concluded*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Río Piedras clay	Upland, deep	Exp. Station, Río Piedras, La Ceiba field	66°3.5′	18°23.3′
Sabana Seca sandy clay loam	Coastal plains, compact	Km. 2.7 Road 46, Río Piedras-Sanatorio	66°4′	18°23.5′
St. Lucie fine sand	do.	0.3 Km. W. Km. 3.3 Arecibo-Lares Road	66°45.5′	18°27.4′
San Antón loam	Flood plains, well drained	Hacienda Esperanza of Central Aguirre, Salinas	66°16′	17°57.5′
Santa Isabel clay	Terraces and alluvial fans, compact	Hacienda Teresa of Central Aguirre, Salinas	66°16.5′	17°58′
Soller clay loam, shallow phase	Upland, deep	Km. 25.9 Road 34, San Sebastián-Guajataca	66°59′	18°21′
Tanamá stony clay	Upland, shallow	Km. 149.1 Road 2, E. Aguada	67°10′	18°23.5′
Teja loam	Upland, deep	Km. 92.3 Road 3, Humacao-Yabucoa	65°50.7′	18°5.7′
Toa silty clay loam	Flood plains, well drained	Finca Javieri, Central Eureka, 1.9 Km. S. Hormigueros	67°8′	18°7′
Utuado loam	Upland, deep	Demonstration farm, Utuado	66°42′	18°16′
Viví sandy loam	Flood plains, well drained	Km. 97.6 Road 3, Humacao-Yabucoa	65°52.5′	18°4′

composition and the presence and abundance of the various mineral groups estimated.

THE MINERALS OF THE ROCKS

The rock samples secured along with the soils consisted of andesites, quartz diorites, basalts, serpentines, limestones, sandstones, and shales. The minerals identified in these rocks in standard thin sections are given in table 3.

The important minerals from the standpoint of soil formation are

TABLE 2.—*Classification of soil series studied in arid and humid areas, according to soil groups (13)*

Zonal								Intrazonal				Azonal soils		
Gray-Brown	Red and yellow podzolic	Reddish-brown lateritic	Yellowish brown lateritic	Laterite	Reddish prairie	Reddish chestnut	Reddish brown	Rendzina	Planosol	Ground water podzol	Wiesenboden	Alluvial	Lithosols and shallow soils	Sands
Humid Area					*Arid Area*									
Ciales	Cabo Rojo	Alonso	Coto	Nipe	—	Fraternidad	Jácana	—	—	—	—	—	—	—
Humacao	Lares	Bayamón	—	—										
Juncos	Los Guineos	Catalina	—	—										
Las Piedras	Moca	Cialitos	—	—	Paso Seco	—	—	Aguilita	Santa Isabel	—	Guánica	Aguirre San Antón	Descalabrado	—
Teja	—	Islote	—	—										
Utuado	—	Maleza	—	—	*Humid Area*									
		Matanzas	—	—										
		Río Piedras	—	—	—	—	—	—	—	—	—	—	—	—
					Mabí	—	—	Soller	Guayabo	—	—	—	Múcara	—
					—	—	—	—	Sabana Seca	Corozo	—	Coloso	Pandura	St. Lucie
					—	—	—	—	—	—	—	Toa	Tanamá	—
					—	—	—	—	—	—	—	Viví	—	—
					—	—	—	—	—	—	—	—	—	—

quartz, the feldspars, hornblende, and biotite. It is of interest to note the lack of microcline, orthoclase, muscovite, and certain common accessories notably, tourmaline. The only mineral noted that contains appreciable potassium is biotite.

MECHANICAL ANALYSIS OF THE SOILS

Before mechanical analysis the free iron oxides were removed using the nascent hydrogen methods described by Jeffries (6, 7). Then the iron-free soils were dispersed and separated into their sand, silt, and clay fractions. The very fine sand fraction was separated from the total sands by methods described by Marshall and Jeffries (12).

Table 4 shows the soil series, arranged in physiographic areas, depth of sampling, the content of the various size separates, and the loss on removal of the free iron oxides.

TABLE 3.—*Minerals present in rocks of Puerto Rico collected*

Quartz	Hornblende	Apatite	Magnetite
Albite	Augite	Hypersthene	Chromite
Oligoclase	Biotite	Olivine	Calcite
Andesine	Chlorite	Zircon	Cordierite
Labradorite	Serpentine	Rutile	Sericite
—	Titanite	—	Epidote

THE CONSTITUENT MINERALS OF THE SOILS

The constituent minerals as determined in this study consisted of the quartz, feldspar, and clay-mineral groups. As was previously stated another group of minerals is of great importance in soils in general—the muscovite mica group, but no muscovite mica was identified in any of the soils studied. This is of interest and will be discussed later. Therefore, three constituent mineral groups will be considered. In general, quartz was identified in all the very fine sand and silt fractions and in some clay fractions. Feldspar occurred in varying quantities in 21 of the profiles studied and was entirely absent, or was present in minute traces only, in the other profiles. The chief feldspars identified were oligoclase, albite, and andesine, with varying small amounts of labradorite and, in a very few cases, extremely small quantities of orthoclase. In most cases the feldspar fraction was a mixture of these feldspars. As a rule, however, one feldspar was the most abundant and it was generally, albite or oligoclase.

The distribution of feldspar in the soil profiles was of decided interest. In some cases the quantities of feldspar decreased with depth, and quartz increased; in other cases the reverse was true. Some of the inferences from this finding will be discussed later.

TABLE 4.—*Mechanical analyses of soil samples by physiographic regions*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
			Upland deep				
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Alonso	91	8–18	5.75	5.93	34.67	23.50	30.15
	90	18–32	7.29	6.76	26.75	22.00	37.20
Catalina	172	[2]	2.65	8.80	19.23	26.27	43.05
	81	[3]	.93	4.37	22.82	43.95	27.93
Cialitos	84	33–20	.37	2.68	28.35	45.00	23.60
	83	33–45	1.30	5.65	15.20	48.30	29.55
Ciales	93	[2]	16.48	25.95	41.62	9.15	6.80
	92	[3]	52.04	20.87	9.89	9.25	7.95
Juncos	58	0–8	6.06	15.92	23.72	33.05	21.25
	57	8–15	13.46	13.40	32.29	26.35	14.50
Los Guineos	186	0–24	77.60	5.70	2.25	3.70	10.75
	185	24–43	55.90	6.15	10.27	23.15	4.53
	184	32–48	37.35	8.45	15.65	17.36	21.19
	183	48+	38.75	10.05	16.65	17.20	17.35
Múcara	9	0–10	22.79	13.40	9.90	24.55	29.36
	8	10–18	38.90	17.10	7.50	13.26	23.24
	7	18–30	54.85	10.95	3.70	10.05	20.45
	6	30+	39.55	14.00	3.55	13.35	29.55
Nipe	16	0–16	36.00	10.54	3.10	23.30	27.06
	17	16–36	6.59	.87	.95	28.65	62.94
	18	36–120	14.35	.58	.80	20.12	64.15
	19	120–240	.81	.20	.33	18.42	80.24
	156	[4]	12.25	4.92	2.68	25.97	54.18
	157	[4]	5.78	3.05	3.40	44.37	43.40
Pandura	62	0–12	65.69	16.91	4.40	6.45	6.55
	61	12–24	73.45	5.20	3.90	8.35	9.10
	60	24+	47.35	7.10	7.60	28.55	9.40
Soller	117	[2]	.75	2.25	5.80	53.80	37.40
Teja	71	0–12	43.72	25.92	11.41	12.35	6.60
	70	12+	64.25	5.50	7.70	10.40	12.15

TABLE 4.—*Continued*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Upland deep (continued)							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Utuado	98	0–24	59.30	11.75	8.85	11.35	8.75
	97	24–56	14.00	30.80	22.10	19.40	13.70
	96	56–64	26.65	26.25	19.45	13.85	13.80
	95	72–64	71.40	10.55	5.10	6.45	6.50
Río Piedras	190	[2]	4.10	3.68	12.70	62.17	17.35
Upland shallow							
Aguilita	103	0–12	4.14	3.96	27.71	29.66	34.53
Tanamá	109	[2]	12.90	10.35	22.15	36.70	17.90
Descalabrado	23	0–10	28.90	17.80	15.20	20.05	18.05
	24	10–24	17.77	20.90	20.45	26.55	14.33
	25	24+	29.10	20.04	16.95	21.75	12.16
Jácana	4	0–7	14.50	13.05	18.85	23.46	30.14
	3	7–12	20.10	10.55	13.89	23.80	31.66
Inner plains							
Cabo Rojo	135	0–24	21.07	13.25	25.50	26.35	13.83
	134	24–36	12.30	13.58	29.32	34.25	10.55
	132	36+	10.12	14.16	22.12	32.80	20.80
Las Piedras	66	0–20	59.30	11.27	7.03	15.50	6.90
	65	20–44	61.80	9.35	4.10	14.85	9.90
	64	44–48	47.35	7.10	7.60	28.55	9.40
	63	48+	73.45	5.20	3.90	8.35	9.10
Mabí	15	0–10	13.05	21.95	14.80	24.25	25.95
	14	10–30	12.05	19.69	13.20	31.45	23.61
	13	30+	17.75	14.25	11.10	27.30	29.60
Moca	106	[2]	3.60	12.60	7.20	46.60	30.00
Terraces and alluvial fans—medium friable							
Humacao	68	0–20	37.62	26.26	12.12	14.70	9.30
	67	20–44	23.30	20.05	16.80	28.90	10.95
Lares	114	0–60	11.48	7.75	12.92	35.25	32.60
	113	60+	11.00	5.80	13.95	44.95	24.30

TABLE 4.—*Continued*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Terraces and alluvial fans—compact							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fraternidad	30	0–7	35.48	15.30	10.30	28.40	10.52
	39	7–18	30.75	9.95	13.40	44.25	1.65
	28	18–36	16.40	11.45	14.40	40.05	17.70
	28B	36+	18.65	12.10	11.10	41.01	17.14
Paso Seco	37	0–10	25.15	20.55	11.05	28.80	14.45
	36	10–18	35.10	18.00	11.35	12.90	22.65
	35	22–35	17.37	28.23	17.35	22.70	14.35
Santa Isabel	44	0–8	21.54	23.59	18.32	22.75	13.80
	43	8–16	46.10	10.37	8.17	23.41	11.95
	42	16–24	28.95	10.80	9.15	27.30	23.80
Coastal plains							
Sabana Seca	194	0–12	57.05	5.45	6.30	21.50	9.70
	193	12+	80.75	9.72	5.70	3.83	—
Coto	122	[2]	6.26	3.16	13.78	23.00	53.80
Bayamón	165	0–18	50.83	7.62	2.37	25.25	13.93
	164	18–24	14.90	2.10	1.20	59.70	22.10
Matanzas	119	[2]	1.75	2.25	5.80	53.80	37.40
Corozo	147	0–2	93.75	1.15	.20	3.05	1.85
	150	2–12	91.90	1.00	.20	3.30	3.60
Guayabo	105	12–36	71.02	12.93	5.22	5.65	5.18
	104	36+	52.30	2.05	1.50	28.80	15.35
Islote	141	0–40	89.00	1.90	1.75	1.30	6.05
Maleza	101	[2]	89.85	.95	.80	3.90	4.50
St. Lucie	169	[5]	65.85	2.05	4.05	23.50	4.55
Flood plains							
Vivi	73	0–15	43.23	28.14	9.48	14.40	4.75
	72	15+	62.06	24.64	6.55	4.30	2.45

TABLE 4.—*Concluded*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
			Flood plains (continued)				
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
San Antón	41	0–24	12.04	26.76	25.05	20.50	15.65
	40	24–29	22.84	27.61	18.25	16.80	14.50
	39	29–44	15.20	21.00	12.00	22.65	29.15
	38	44+	61.60	5.85	5.00	7.75	19.80
Toa	52	0–16	4.45	18.45	13.85	29.55	33.70
	51	16–34	.92	21.30	18.88	35.30	23.60
	50	34–46	3.95	11.65	15.00	39.00	30.40
Aguirre	31	0–10	27.20	7.90	8.40	30.26	26.24
	32	10+	12.59	17.77	17.26	31.83	20.25
Coloso	49	0–10	14.60	11.45	14.45	38.95	20.55
	48	10–34	5.93	8.95	19.92	45.15	20.05
	47	34–52	1.15	9.05	23.80	47.20	18.80
	46	52+	.98	8.32	24.17	47.68	18.85
Guánica	34	[2]	6.87	18.26	12.62	38.35	23.90
	33	[3]	12.20	8.77	11.28	41.80	25.95

[1] Includes free or hydrated oxides of iron, aluminum and titanium, free silica, carbonates, organic matter, and soluble cations and salts.

[2] Surface.

[3] Subsoil.

[4] Soil below concretions.

[5] Subsurface.

A few of the very fine sand and silt fractions which contained no feldspar were of interest in that they consisted almost wholly of some quartz and large plates of kaolin. This was particularly true in the Los Guineos soil but was also noted in several other highly weathered soil profiles.

The clay minerals identified were kaolin, illite, montmorillonite, and one identified tentatively as beidellite. The most abundant clay minerals were kaolin and the beidellitelike mineral, illite was next in abundance, followed by montmorillonite. In some cases the clay fractions were mixtures, but in many they were apparently very well-developed single clay minerals. Where illite or chlorite was identified in the upper horizons weathering reactions changed these minerals in the lower horizons to kaolin or beidellite.

The constituent minerals identified in the very fine sand, silt, and clay

fractions of the soils indicated, and their relative abundance in the soil profile are shown in table 5. For convenience the soils have been arranged according to the physiographic areas in which they occur.

The method of determining the presence of the various mineral groups was by comparing typical X-ray patterns of the soil fractions with those of known minerals. In addition to X-ray patterns of the very fine sand fractions, petrographic examinations were carried out to determine the presence or absence of small quantities of feldspar which would not be apparent in the X-ray patterns.

DISCUSSION OF FINDINGS

This study was conducted on the very fine sand, silt, and clay fractions of the soils indicated from which the free iron oxides had been removed. The soils studied were of the zonal, intrazonal and azonal orders and were from 15 of the great soil groups, as shown in table 2. In most cases soil profiles were studied; in a few, however, where it was impossible to secure profile samples, surface soils alone were investigated.

The constituent minerals of soils which have been previously discussed are those of the quartz, feldspar, mica, and clay-mineral groups. Study of the X-ray patterns showed that the muscovite mica group was not present in the soils studied, consequently any comparisons made are based on the quartz, feldspar, and clay-mineral groups. The presence or absence of feldspar in the various soils studied (table 5) showed that in the upland soils, which included a group of 17 soil series, 8 contained feldspars in appreciable quantities, 1 in very small quantities and feldspars were completely absent or were present in only minute traces in the other 8. Feldspars were present in 2 of the soils of the inner plains, and absent in 2. The group of soils from the terraces and alluvial fans included 4 soils containing feldspars and one without. All the soils of the coastal plains were practically free of feldspars; the river flood plain soils, however, all contained appreciable quantities Table 6 gives the soil series with and without feldspars.

Further study of the soils which contained feldspars showed that the feldspar content of the various horizons decreased with depth in some soils; in others it increased in the sand and silt fractions as has been previously noted.

Twenty-one of the soil series studied contained feldspars. It was noted that in 9 of these series the feldspar content of the very fine sand and silt fractions decreased with depth in the profile, and in 12 of them the feldspars increased with depth.

The feldspars typical of all soils were of the plagioclase series. The plagioclase feldspar series consists of solid solution mixtures of the albite

TABLE 5.—*Soil series and distribution of feldspars and clay minerals in the physiographic arid and humid areas*

Soil series	Physiographic arid or humid areas	Layer or depth of profile	Feldspar				Clay minerals identified and variations in profile[1]
			Relative abundance	Varieties	Variation in profile[1]		
					Very fine sand	Silt	
		Inches					
Aguilita	Upland, shallow, arid	[2]	Absent	—			Beidellite
Alonso	Upland deep, humid	8–18	Medium	Oligoclase	↑	↑	Kaolin
		18–32	—	do.			Do.
Catalina	do.	[2]	Absent	—			Do.
Ciales	do.	[2]	Medium	Oligoclase, andesine,	↓	↓	Kaolin + illite
		[3]	—	traces of labradorite and albite			Do.
Cialitos	do.	20–33	Absent	—			Kaolin, traces of illite
		33–45	—	—			Do.
Juncos	do.	0–8	Very high	Albite, andesine, trace of orthoclase		↑	Montmorillonite; Kaolin
		8–15	—	—			Montmorillonite; Kaolin, illite
Los Guineos	do.	0–24	Absent	—			Kaolin
		24–32	—	—			Do.
		32–48	—	—			Do.
		48+	—	—			Do.
Múcara	do.	0–10	Very high	Andesine			Beidellite
		10–18	—	Andesine, labradorite			Do.
		18–30	—	do.			Do.
		30+	—	do.	↓	↓	Do.

TABLE 5.—*Continued*

Nipe	do.		Absent	—			Kaolin
Pandura	do.	0–12	High	Albite, trace of oligoclase and andesine	↓	↓	Kaolin, illite
		12–24	—	—	↓	↓	Do.
		24+	—	—	↓	↓	Kaolin
Soller	do.	[2]	Absent	—			Do.
Tanamá	do.	[2]	do.	—			Do.
Teja	do.	0–12	Very high	Oligoclase, albite	↓	↓	Do.
		12+	—	—	↓	↓	Do.
Utuado	do.	0–24	Very low	Oligoclase and albite	↑		Do.
		24–56	—	—	↑	absent	Do.
		56–64	—	—	↑		Do.
		64–72	—	—	↑		Do.
Río Piedras	do.	[2]	Absent	—			Do.
Descalabrado	Upland shallow, arid	0–10	Medium	Oligoclase, albite	↑	↑	Illite
		10–24	—	—	↑	↑	—
		24+	—	—	↑	↑	—
Jácana	do.	0–7	High	Oligoclase, albite	↓	↓	—
		7–12	—	—	↓	↓	—
Cabo Rojo	Inner plains, humid	0–24	Absent	—			Beidellite
		24–36	—	—			Do.
		36+	—	—			Kaolin, montmorillonite
Las Piedras	do.	0–20	Very high	Albite, andesine, traces of orthoclase	↓	↓	Kaolin ↑
		20–44	—	Andesine, albite	↓	↓	↑
		44–48	—	Albite, oligoclase	↓	↓	↑
		48+	—	Albite	↓	↓	Beidellite

TABLE 5.—*Continued*

Soil series	Physiographic arid or humid areas	Layer or depth of profile	Feldspars				Clay minerals identified and variations in profile[1]
			Relative abundance	Varieties	Variation in profile[1]		
					Very fine sand	Silt	
		Inches					
Mabí	Inner planes, humid	0–10	High	Oligoclase, albite	↑	↑	Kaolin, illite
		10–30	—	—			↑ ↑
		30+	—	—			Beidellite
Moca	do.	[2]	Absent	—			Kaolin, montmorillonite, illite
Lares	Terraces medium friable, humid	0–5	do.	—			Kaolin
		5+	—	—			Do.
Humacao	Terrace and alluvial fans, humid	0–20	High	Oligoclase, albite	↓	↓	Do.
		20–44	—	—			Do.
Fraternidad	Terraces and alluvial fans, arid	0–7	Very low	Albite, labradorite	↑	↑	Beidellite (carbonates)
		7–18	—	do.			—
		18–36	—	do.			—
		36+	—	do.			—
Paso Seco	do.	0–10	—	Albite	↓	↓	Kaolin, illite
		10–18	—	—			—
		22–35	—	—			—
Santa Isabel	Terraces and alluvial fans, compact, arid	0–8	High	Oligoclase, albite, labradorite	↑	↑	Kaolin, illite
		8–16	—	—			—
		16–24	—	—			—
Corozo	Coastal plains, humid	0–2	Absent	—			Kaolin
		2–12	do.	—			Do.
Islote	do.	0–40	—	—			Kaolin, illite
Sabana Grande	Coastal plains, compact, humid	0–12	Absent	—			Kaolin
		12+	—	—			Do.

TABLE 5.—*Concluded*

St. Lucie	do.	[2]	Absent	—			Do.
Coto	Coastal plains, friable, humid	[2]	Do.	—			Do.
Bayamón	do.	0–18	Absent	—			Do.
		18–24	—	—			Do.
Matanzas	do.	[2]	Absent	—			Do.
San Antón	Flood plains, well-drained, arid	0–24	High	Oligoclase, albite labradorite	↑	↓	Illite, kaolin, chlorite
		24–29	—	do.			↑ ↑ ↑
		29–44	—	do.			↑ ↑
		44+	—	—		↓	Beidellite
Toa	Flood plains, well-drained, humid	0–16	High	Albite			Kaolin
		16–34	—	do.			↑
		34–46	—	do.	↓	↓	Beidellite
Viví	Flood plains, well-drained	0–15	Very high	Oligoclase, andesine, albite		↑	Kaolin
		15+	—	—	↓		—
Aguirre	Flood and coastal plains, poorly drained, arid	0–10	Medium	Albite			Beidellite
		10+	—	do.	↓	↓	Do.
Coloso	Flood plains, poorly drained, humid	0–10	Medium	Albite, oligoclase, orthoclase		↑	Kaolin
		10–34	—	—			Do.
		34–52	—	—			Do.
		52+	—	—			Do.
Guánica	Flood plains, poorly drained, arid	[2]	High	Albite, andesine	↓	↓	Beidellite
		[3]	—	—			Do.

[1] Arrow pointing up, down, and straight vertical line, indicate decrease, increase, and no change in feldspars, with depth, respectively.

[2] Surface. [3] Subsoil.

molecule Ab. ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) and anorthite An. ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). Albite and anorthite are designated as end members of the series and the intermediate compositions are generally expressed in the percentage distribution of the albite and anorthite molecules. Table 7 gives the plagioclase series, variety names, and limits of composition.

TABLE 6.—*Soil series of Puerto Rico studied in which feldspars are present or absent*

Feldspars present	Feldspars present	Feldspars absent	Feldspars absent
Alonso	Mabí	Aguilita	Corozo
Ciales	Humacao	Catalina	Maleza
Juncos	Viví	Cialitos	Guayabo
Múcara	Fraternidad	Los Guineos	Islote
Pandura	Paso Seco	Soller	Sabana Seca
Teja	Santa Isabel	Tanamá	St. Lucie
Utuado	San Antón	Río Piedras	Coto
Descalabrado	Toa	Cabo Rojo	Bayamón
Jácana	Aguirre	Moca	Matanzas
Las Piedras	Coloso	Lares	Nipe
—	Guánica	—	—

TABLE 7.—*Variety names and composition limits of plagioclase feldspar series*

Variety name	Composition limits	Variety name	Composition limits
Albite	Ab_{10}-Ab_9An_1	Labradorite	Ab_5An_5-Ab_7An_3
Oligoclase	Ab_9An_1-Ab_7An_3	Bytownite	Ab_7An_3-Ab_1An_9
Andesine	Ab_7An_3-Ab_5An_5	Anorthite	An_{10}

TABLE 8.—*Comparison of the clay content of soils containing feldspars and those containing no feldspars in soils of the upland, inner plain, terraces, and alluvial fans*

Physiographic group	Clay content with feldspars present	Clay content with feldspars absent
	Percent	*Percent*
Upland soils	18.24	28.50
Inner plain soils	21.48	39.41
Terraces and alluvial fans	15.58	40.20

In the 21 soil series that contained appreciable quantities of feldspars the predominant feldspar was albite in 8 cases, oligoclase in 12, and andesine in 1. Minor quantities of andesine and labradorite were observed in many soils where the very fine sand and silt fractions were predominantly albite or oligoclase.

Study of the mechanical analyses in table 4 showed that, where comparisons could be made, the soils containing appreciable quantities of feldspar

TABLE 9.—*Clay content, cation-exchange capacity, and clay minerals present in the soils from Puerto Rico*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish Brown	Jácana clay	3	12+[1]	23.80	26.11	Beidellite + kaolinite
		4	0–7[2]	23.46	22.63	Do.
Gray-brown podzolic or lithosol depending on depth and slope	Múcara silty clay loam	6	30+	13.35	36.71	Beidellite
		7	18–30	10.05	29.75	Do.
		8	10–18	13.26	31.04	Do.
		9	0–10	24.55	36.04	Do.
Reddish prairie	Mabí clay	13	30+	27.30	31.65	Beidellite
		14	10–30	31.45	34.02	—
		15	0–10	24.25	31.17	Kaolinite + illite
Lithosol associated with Prairie, Chernozem and Chestnut soils	Descalabrado silty clay	23	0–10	20.05	16.97	—
		24	10–18[1]	26.55	22.27	Illite
		25	24[3]	21.75	16.46	—
		26	[4]	29.70	19.78	—
Reddish chestnut	Fraternidad clay	28	18–36	40.05	15.19	—
		28B	36[5]	41.01	13.18	—
		29	7–18[6]	44.25	11.23	Beidellite
		30	0–7	28.40	21.03	Do.
Alluvial, poorly drained	Aguirre clay	31	0–10	30.26	42.06	Beidellite
		32	10+	31.83	26.20	Do.
Wiesenboden	Guánica clay	33	[7]	41.80	39.56	Beidellite
		34	[2]	38.35	43.20	Do.
Reddish prairie	Paso Seco silty clay	35	10–18	22.70	16.80	Kaolinite + illite
		36	0–10	12.90	20.10	—
		37	22–35	28.80	19.62	—
Alluvial, well-drained, semiarid and subhumid area	San Antón loam	38	44+	7.75	11.16	Beidellite
		39	29–44	22.65	22.63	—
		40	24–29	16.80	18.83	—
		41	0–24	20.50	23.74	Illite + kaolinite + chlorite

TABLE 9.—*Continued*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish Chestnut, sometimes classified as a planosol	Santa Isabel clay	42	16–24	27.30	23.74	—
		43	8–16	23.41	23.08	—
		44	0–8	22.75	22.02	Kaolinite + illite
Alluvial, poorly drained, humid area	Coloso silty clay	46	52+	47.68	35.13	—
		47	34–52	47.20	35.51	—
		48	10–34	45.15	31.59	Kaolinite
		49	0–10	38.95	38.61	—
Alluvial, well-drained, humid area	Toa silty clay loam	50	34–46	39.00	37.20	Beidellite
		51	16–36	35.30	35.91	Kaolinite
		52	0–16	29.55	34.97	—
Gray-brown podzolic	Juncos clay	57	15–18	26.35	58.32	Montmorillonite + Illite and Kaolinite
		58	0–8	33.05	51.64	Montmorillonite and Kaolinite
Lithosol closely related to gray-brown podzolic	Pandura sandy clay loam	60	24+	7.20	7.61	Kaolinite
		61	12–24	5.00	6.93	Kaolinite + Illite
		62	0–12	6.45	8.16	Kaolinite + Illite
Gray-brown podzolic	Las Piedras clay loam	63	48+	8.35	12.18	—
		64	44–48	28.55	24.75	Beidellite
		65	20–44	14.85	9.04	—
		66	0–20	15.50	7.06	Kaolinite
Do.	Humacao loam	67	24+	28.90	14.56	Kaolinite
		68	0–24	14.70	11.39	Do.
Do.	Teja loam	70	12+	10.40	7.94	Kaolinite
		71	0–12	12.35	8.21	Do.
Alluvial, well-drained, subhumid area	Viví sandy loam	72	15+	4.30	4.85	Kaolinite
		73	0–15	14.40	7.70	Do.

TABLE 9.—*Continued*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish-brown lateric	Catalina clay	81	[8]	43.95	10.77	Kaolinite
Reddish-brown lateric	Cialitos clay	83	33–45	48.30	17.83	Kaolinite
		83B	[9]	19.05	13.34	Do.
		84	20–33	45.00	14.24	Do.
		85	[10]	42.05	29.10	Do.
		87	[11]	3.90	5.84	Illite + Kaolinite
Reddish-brown lateritic	Alonso clay	90	32+	22.00	56.34	—
		91	8–18	23.50	43.04	—
Gray-brown podzolic	Ciales clay loam	92	[7]	9.25	11.80	—
		93	[12]	9.15	9.87	Kaolinite + Illite
Gray-brown podzolic or Lithosol, depending on depth and slope	Utuado loam	95	64–72	6.45	4.27	Kaolinite
		96	56–64	13.85	9.15	Do.
		97	24–56	19.40	10.77	Do.
		98	0–24	11.35	5.22	Do.
Planosol	Guayabo fine sand	104	36+	28.80	7.95	Kaolinite
		105	12–36	5.65	2.20	Do.
Red-and-yellow podzolic	Moca clay	106	[7]	46.60	34.11	Kaolinite, Montmorillonite, Illite
Lithosol related to the Reddish-brown lateritic	Tanamá stony clay	108	[2]	51.65	8.46	Kaolinite
		109	[13]	36.70	7.05	Do.
Red-and-yellow podzolic	Lares clay	113	60+	44.95	22.60	Kaolinite
		114	0–60[2]	35.25	16.54	Do.
Rendzina	Soller clay	117	0–18	53.80	63.53	Beidellite
Reddish-brown lateritic	Matanzas clay	119	[2]	60.50	7.12	Kaolinite
Yellowish-brown lateritic	Coto clay	122	[2]	23.00	7.70	Kaolinite

TABLE 9.—*Concluded*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Red-and-yellow podzolic	Cabo Rojo clay	132	36+	32.80	[14]	Kaolinite + Montmorillonite
		134	24–36	34.25	11.29	Beidellite
		135	0–24	26.35	14.08	Do.
		137	[15]	57.23	57.58	Do.
Laterite	Nipe clay	156	[16]	25.97	.78	Kaolinite
		157	[17]	44.37	.82	Do.
		159	[18]	9.38	19.94	Kaolinite + serpentine
		160	0–24[19]	.87	.82	—
Reddish-brown lateritic	Bayamón sandy clay	164	18–24	59.70	5.47	Kaolinite
		165	0–18[2]	25.25	5.22	Do.
		167	[20]	9.00	4.08	Do.
Ground-water podzolic	St. Lucie fine sand	169	[21]	23.50	3.48	Kaolinite
Reddish-brown lateritic	Catalina stony clay	172	[2]	26.27	11.16	Kaolinite
Red-and-yellow podzolic	Los Guineos clay	176	[22]	27.90	4.52	Kaolinite
		182	[23]	16.95	25.91	Beidellite
		183	48	17.20	7.44	Kaolinite
		184	32–48	17.36	7.57	Do.
		185	24–32	23.15	9.18	Do.
		186	0–24	3.70	8.70	Do.
Reddish-brown lateritic	Río Piedras clay	190	[2]	62.17	15.11	Kaolinite
Planosol or ground-water laterite	Sabana-Seca sandy clay	193	[24]	3.83	.47	Kaolinite
		194	0–12[2]	21.50	7.11	Do.

[1] B Horizon.
[2] Surface.
[3] C Horizon.
[4] Yellow decomposed rock.
[5] Below.
[6] Hard-layer pebbles.
[7] Subsoil.
[8] Soil directly from rock.
[9] Rock.
[10] Ashlike material.
[11] Weathered sandstone.
[12] Disintegrated rock.
[13] Soft limestone.
[14] Sample lost.
[15] Green clay.
[16] Below concretions.
[17] Above concretions.
[18] Residue.
[19] Soil.
[20] Sandy soil.
[21] Clay layer.
[22] Decomposed rock.
[23] Decomposed parent material.
[24] Organic-sandy layer.

had on the average a lower clay content than those containing none, or minute traces only. Table 8 shows these average figures for soils of the upland, inner plains, and terrace and alluvial fan groups.

The clay content, cation-exchange capacity, and clay minerals present in 38 soils series studied, comprising 99 samples at various depths, are reported in table 9. The clay minerals identified consisted of kaolinite, illite, montmorillonite, chlorite, and a mineral identified tentatively as beidellite. The soil samples wherein kaolinite was identified had the lowest mean clay content and cation-exchange capacity (table 10) and those in which montmorillonite was found had the highest. The mean cation-exchange capacity for soils containing beidellite and montmorillonite were approximately three and five times higher, respectively, than those containing kaolinite.

TABLE 10.—*Mean clay content, cation-exchange capacity, and clay-mineral content of soil samples studied*

Number of samples	Clay content	Cation exchange capacity	Mineral
	Percent	*M.e./100 gm. soil*	
42	26.57	10.07	Kaolinite
1	26.60	22.30	Illite
20	29.96	31.41	Beidellite
3	35.30	48.00	Montmorillonite

In the upland soils containing feldspar, kaolin was the predominating clay mineral with one exception (Descalabrado) where illite predominated. With the kaolin were varying quantities of montmorillonite, illite, and the beidellite mineral. Where no feldspar occurred kaolin was predominant with small quantities of illite.

The inner plains soils contained beidellite predominantly, apparently being formed from kaolin and, in addition, small quantities of illite and montmorillonite occurred.

In the terrace and alluvial fans kaolin was generally found with beidellite and illite.

In the coastal-plains soils where no feldspar was observed kaolin predominated, and in the river flood-plains soils, all of which contained feldspar, beidellite was the chief clay mineral with traces of illite and chlorite.

It was interesting to note that in many instances the beidellitelike mineral was formed in the lower horizons of soils in which the feldspar content of the very fine sand and silt fractions increased with depth. This can be seen in table 5 for Las Piedras, San Antón, and Toa. Where feldspar decreased with depth, kaolin appeared to predominate throughout the profile. Where

illite and chlorite occurred in the upper horizons, weathering reactions appeared to change these clay minerals to beidellite. In the San Antón soil, illite, kaolin, and chlorite occur in the 0–24-inch horizon, chlorite does not occur in the 24–29-inch horizon, illite and kaolin persist to a depth of 44 inches, and beidellite occurs at 44 inches +. Apparently under the extreme weathering conditions in the Tropics, chlorite and illite are not very resistant.

In the course of this study some interesting observations were made which appear to lead to some valuable information. From the standpoint of the presence and absence of feldspars which has been noted previously herein, comparisons of the productivity ratings of these soils as reported in the Soil Survey Report (13) show that those containing feldspar have a productivity rating almost three times as high as those containing none, except where lack of rainfall and excessive erosion are factors.

Another comparison was based on the presence of available potassium. In a study using Hegari sorghum as a plant index (5) Capó determined the relative availability of nitrogen, phosphorus, and potassium in 56 soils of Puerto Rico. Included in that study were 25 of the soil series reported here. Fourteen of these soils contained feldspar in the very fine sand and silt fractions, and 11 did not. The average relative available potassium of these two groups showed that the soils containing feldspar also contained 2.2 times as much available potassium as those in which no feldspar occurred. Since the feldspars in these soils are plagioclase and should contain no potassium, and also since muscovite, another common potash mineral does not occur, the source of this available potash is of interest. As shown in table 8, the average clay content of the soils containing feldspar is lower than that of those which do not.

The evidence suggests that the feldspar minerals might constitute a source of potash. Winchell (15) stated that, under certain conditions, the albite molecule forms three crystal phases with sanidine, adularia, and microcline, all of which are potash feldspars of the general formula $K_2O \cdot Al_2O_3 \cdot 6SiO_2$. In general, calling the potash feldspar orthoclase for comparative purposes, and using the abbreviations Or for orthoclase and Ab for albite, Winchell mentioned three possible series, vis, $Or_{50}Ab_{50}$ to about $Or_{10}Ab_{90}$, $Or_{80}Ab_{20}$ to about $Or_{40}Ab_{60}$ and $Or_{40}Ab_{60}$ to $Or_{10}Ab_{90}$.

SUMMARY

The constituent minerals in the very fine sand, silt, and clay fractions of some of the important soils of Puerto Rico were studied using petrographic and X-ray methods.

It was found that these soils could be divided into two general groups: Those that contained appreciable feldspar and those in which feldspars

were totally absent or occurred in minute traces. Study of the profile characteristics showed that the feldspar content of the profile allowed a further subdivision into: Those in which the feldspar decreased with depth; and those in which feldspar increased with depth. The feldspars identified consisted almost exclusively of plagioclase, albite, oligoclase, and andesine, these being the principal constituents, with traces of labradorite and very small traces of orthoclase.

The clay minerals identified in the soil studied consist of either kaolin, hydrous mica, or illite, one tentatively identified as beidellite, and montmorillonite, with mean cation-exchange capacities of 10.07, 22.30, 31.41, and 48.00 milliequivalents per 100 gm. of soil, respectively. Some soils contained a combination of two or three of these clay minerals. In the upland soils where feldspar occurred, kaolin was the predominating mineral with varying quantities of hydrous mica and montmorillonite. Where no feldspar occurred in the upland soils, the clay mineral was principally kaolin. The inner-plains soils chiefly contained beidellite, regardless of whether feldspar was present or not. Five soils of the terraces and alluvial fans contained feldspar and one did not, and kaolin was the principal clay mineral. The river flood-plain soils all contained feldspar and beidellite was the predominant clay mineral. The coastal-plain soils contained no feldspar and kaolin predominated.

The occurrence of the feldspar in a profile seems to have some bearing on the clay minerals formed by the weathering processes. Where feldspars increased with depth, beidellite seemed to be the ultimate clay mineral formed. Where feldspar decreased, the clay mineral formed was kaolin.

By comparing the presence or absence of feldspar with the productivity rating as determined by the Soil Survey of Puerto Rico, it was found that soils containing feldspar had a much higher productivity rating than those from which it was absent, or in which it occurred only in small traces—also that soils containing feldspar had a lower clay content than those which did not.

If the available potash content using Hegari sorghum was regarded as a plant index, comparisons showed that soils containing feldspar also contained about 2.2 times more available potash than those lacking feldspar.

In general, the results obtained indicate that the most productive soils studied were those that contained fairly large quantities of feldspar, had a low clay content, and the clay minerals of which were mixtures of kaolin, hydrous mica, and beidellite and, in some cases, montmorillonite.

RESUMEN

Los minerales constituyentes de todos los suelos son: el cuarzo, los feldespatos, las micas y los del grupo de la arcilla. Para identificar estos

minerales en los suelos de Puerto Rico que se estudiaron, se trataron las muestras, químicamente, con el objeto de eliminar la materia orgánica y los sesquióxidos de aluminio y de hierro. Los residuos limpios se separaron, mediante el análisis mecánico, en fracciones de arena muy fina, limo y arcilla. Se identificaron los minerales, constituyentes de cada una de estas fracciones, por medio de los métodos petrográficos y de los rayos X.

El cuarzo se encontró en las tres fracciones estudiadas, pero las micas y, especialmente, la mica muscovita que, generalmente, abunda en los suelos, no apareció.

Estos suelos estudiados pueden dividirse en dos grupos amplios; aquéllos que contienen suficiente cantidad de feldespatos y los que contienen indicios o ningún feldespato.

El estudio del perfil señaló también aquellos suelos en que los feldespatos disminuían, a medida que aumentaba su profundidad, y aquéllos donde los feldespatos aumentaban. Los feldespatos principales, identificados, consistían, principalmente, de los grupos plagioclasa, oligoclasa y andesina, con indicios de labradorita e indicios ínfimos de ortoclasa.

Los minerales identificados en el grupo de la arcilla, consistían de caolina, o de mica hidratada, ilita, o montmorillonita, con valores promedios, de intercambio de bases, de 10.07, 22.30, 31.41, y 48.00 miliequivalentes por 100 gramos de suelo, respectivamente.

También se identificó un grupo, tentativamente, como beidelita. Algunos suelos contenían una combinación de dos o tres minerales del grupo de la arcilla.

En los suelos de la altura de Puerto Rico que contenían feldespatos, el mineral predominante era la caolina, con cantidades variables de mica hidratada y montmorillonita. En aquéllos, donde no había feldespatos, el mineral predominante era la caolina, principalmente.

Los suelos del interior contenían beidelita, principalmente, con o sin feldespatos. Cinco suelos del grupo de las terrazas y abanicos de aluvión contenían feldespatos. Sin embargo, el otro suelo del grupo no lo tenía, pero en todos, el mineral predominante era la caolina.

Todos los suelos de las llanuras, sujetos a inundación, contenían feldespatos y beidelita.

Los suelos de las llanuras costaneras no contenían feldespatos, pero la caolina predominaba.

La presencia de los feldespatos en el perfil, señalaba una relación entre los minerales del grupo de la arcilla y el proceso de meteorización. Cuando los feldespatos aumentaban, según la profundidad, la beidelita predominaba, y cuando los primeros disminuían, la caolina predominaba.

En los suelos más fértiles, los feldespatos predominaban y el contenido de arcilla era menor que en los menos fértiles.

Tomando como base el contenido de potasa asimilable, determinado cuando se usó la planta sorgo Hegari, como índice, se encontró que los suelos que contenían feldespatos tenían alrededor de 2.2 veces más potasa asimilable que los que no los contenían.

Los resultados indican que los suelos más productivos fueron aquéllos con mayor cantidad de feldespatos y menor de arcilla. Los minerales de estos suelos más productivos, en el grupo de la arcilla, consistían de mezclas de caolina, mica hidratada, y en algunos casos de montmorillonita.

LITERATURE CITED

1. Bonnet, J. A., Soil mineralogy; Annual Report of the Director, Institute of Tropical Agriculture of P. R., 1943–44, pp. 104–5.
2. Bonnet, J. A., Mineralogical characteristics and mode of formation of tropical soils, Annual Report of the Director, Institute of Tropical Agriculture of P. R., 1944–45, pp. 58–9.
3. Bonnet, J. A., The nature of laterization as revealed by chemical, physical, and mineralogical studies of a lateritic soil profile from Puerto Rico, *Soil Sci.* **48** 25–40 1939.
4. Bonnet, J. A., Broad classification of tropical soils in Puerto Rico by various practical systems, Proceedings of the First Commonwealth Conference of Tropical and Subtropical Soils, 1948, pp. 103–6, Commonwealth, Bureau of Soil Science, Tech. Communication **46,** Harpenden, England, 1949.
5. Capó, B. G., Cantidades asimilables de nutrimentos en los suelos de Puerto Rico (Available nutrients in the soils of Puerto Rico), Informe Bienal, 1938–1940, Estación Experimental Agrícola (Biannual Report, 1938–1940, Agricultural Experiment Station), Río Piedras, P. R., pp. 59–61.
6. Jeffries, C. D., A method of preparing soils for petrographic analysis, *Soil Sci.* **52,** 451–4 1941.
7. Jeffries, C. D., A rapid method for the removal of free iron oxides in soil prior to petrographic analysis, *Soil Sc. Soc. of Amer. Proc.* **11** 211–2 1946.
8. Jeffries, C. D., The use of the X-ray spectrometer in the determination of the essential minerals in soils, *Soil Sci. Soc. of Amer. Proc.* **12** 135–40 1947.
9. Jeffries, C. D., The mineralogical approach to some soil problems, *Soil Sci.* **63** 315–20 1947.
10. Jeffries, C. D. and Jackson, M. L., Mineralogical analysis of soils, *Soil Sci.* **68** 57–73 1949.
11. Jeffries, C. D., Bonnet, J. A., and Abruña, F., Mineral characteristics of some soils of Puerto Rico, *Soil Sci. Soc. of Amer. Proc.* **16**(3) 310–11 July 1952.
12. Marshall, C. E. and Jeffries, C. D., Mineralogical methods in soil research, *Soil Sci. Soc. of Amer. Proc.* **10** 397–405 1945.
13. Roberts, R. C. and party, Soil Survey Puerto Rico, U. S. Department of Agriculture, Bur. of Plant Ind., in coop. with the Univ. of P. R. Agr. Expt. Sta., Series 1936, No. 8, 503 pp., 1942.
14. Thorp, James, Some important soil profiles of southern Puerto Rico, *Soil Sci.* **34** 241–57 1932.
15. Winchell, A. N., Elements of optical mineralogy, An introduction to microscopic petrography: Part II, Description of minerals, p. 298, 4th edition, 551 pp., John Wiley & Sons, Inc., New York, N. Y., 1951.

NEW COLLEMBOLA FROM PUERTO RICO

David L. Wray[1]

INTRODUCTION

The following are some forms of Collembola that have been collected in various regions of Puerto Rico, those appearing new to science being described herein. I wish to thank Professor J. Maldonado Capriles for his kindness in sending me this material for study. It is interesting to find some forms very close to those described by Schött in 1893 from Africa and also some close to those figured by Imms from India.

FORMS OF COLLEMBOLA FOUND IN PUERTO RICO

Genus *Dicranocentrus* Schött, 1893

Genotype: Dicranocentrus gracilis, Schött, 1893, Bihang. Till K. Svenska Vet.-Akad. Handlinger Band 19. Afd. IV. No. 2, pp. 21–23, Taf. VII, figs. 1–5.

In 1893, H. Schött erected the Genus *Dicranocentrus* to receive a new species *gracilis* that he studied from Kamerun. He had two specimens from which to draw his description. His generic description needs amendment only because he recognized four antennal segments in his specimens. Since then Salmon (1951) placed this genus in the *Orchesellini*, and mentioned the six segmented antennae. The one species that I describe below falls within this genus, but differs in certain characters to such an extent that I hesitate to place it finally therein, so have erected the following new subgenus, using Schött's *Dicranocentrus gracilis* as the subgenotype of *Dicranocentrus* s. str., and my new form *Dicranocentrella marias* as the subgenotype for the new subgenus.

Subgenus **Dicranocentrus** s. str.

Subgenotype: Dicranocentrus gracilis, Schött

Orcheselline in general body appearance, fourth abdominal segment not over 1½ times the third. Mesonotum not prominent. Antennae 6-segmented, third segment indistinctly separated from fourth. Scales present. Eyes not studied. Dentes with longitudinal rows of spines. Mucro with two teeth and a basal spine.

Subgenus **Dicranocentrella** new

Subgenotype: Dicranocentrella marias, n. sp.

Orcheselline in general body appearance, with fourth abdominal segment

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not much longer than the third. Antennae 6-segmented, third segment not distinctly separated from fourth, fifth, and sixth annulated. Antennae longer than body and head combined. Scales present. Eyes 16, 8 on each side of head. Dentes with several longitudinal rows of stout spines on proximal half. Mucro with two teeth and a basal spine. This subgenus differs from *Dicranocentrus* Schött in the length of the antennae and the position of the longitudinal rows of dental spines.

Dicranocentrella marias, n. sp.

Length up to 2.25 mm. Background color yellow with a diffusion of purplish pigment scattered over the head and body, heavier on head and lateral margins of thorax. Legs heavily pigmented throughout. Traces of pigment on manubrium. Antennal segments purplish, lighter at joints. Eyespots heavy purple. A dark spot in middle of front of head. Orcheselline in general appearance (fig. 1, Q), the fourth abdominal segment not more than 1½ times the third. Antennae 6-segmented, very long, as long as head and body combined. Third segment indistinctly separated from the fourth (fig. 1, S). Proportions of segments as 15:40:25:50:185:85. First four segments heavily scaled; fifth and sixth annulated. Head, body, and legs heavily scaled. Scales on manubrium and ventrally on dentes. Scales with rounded apices (fig. 1, V). Rami of tenaculum quadridentate. Unguis (fig. 1, U) with outer teeth and with one tooth on inner margin on distal half. Unguiculus unarmed, lanceolate. One unknobbed tenent hair on each tibiotarsus subequal in length to unguis. Hind legs long. Furcula about as long as hind legs. Proportions of manubrium to dentes as 20:38. Dentes with two or three longitudinal rows of stout simple spines situated on proximal third, and with a row of stout curved setae along lateral margins (fig. 1, T). Ventrally, heavily clothed with long scales. Dentes with a basal transverse row of stout setae. Mucro (fig. 1, R) with a long upcurved apical tooth, a stout proximal tooth, and a basal spine. Dentes become very narrow and slender toward apex, the deep dorsal crenulations end about 6 or 7 mucro-lengths from apex. Clothing of thickly set brownish scales, short and longer, much stouter, fringed setae.

Type locality: Las Marias, P.R., 5 km. from town at 500-foot altitude, August 21, 1951. Many specimens taken in litter by J. Maldonado Capriles. Maricao, August 28, 1951, Road 27, 400-foot elevation, J. M. Capriles.

Genus **Dicranocentruga,** new

Paronelloid in general appearance. Fourth abdominal segment long, about half as long as body. Mesonotum not prominent. Furcula long, very slightly diminishing in width throughout its length. Manubrium longer than dentes. Dentes with at least two longitudinal rows of stout spines.

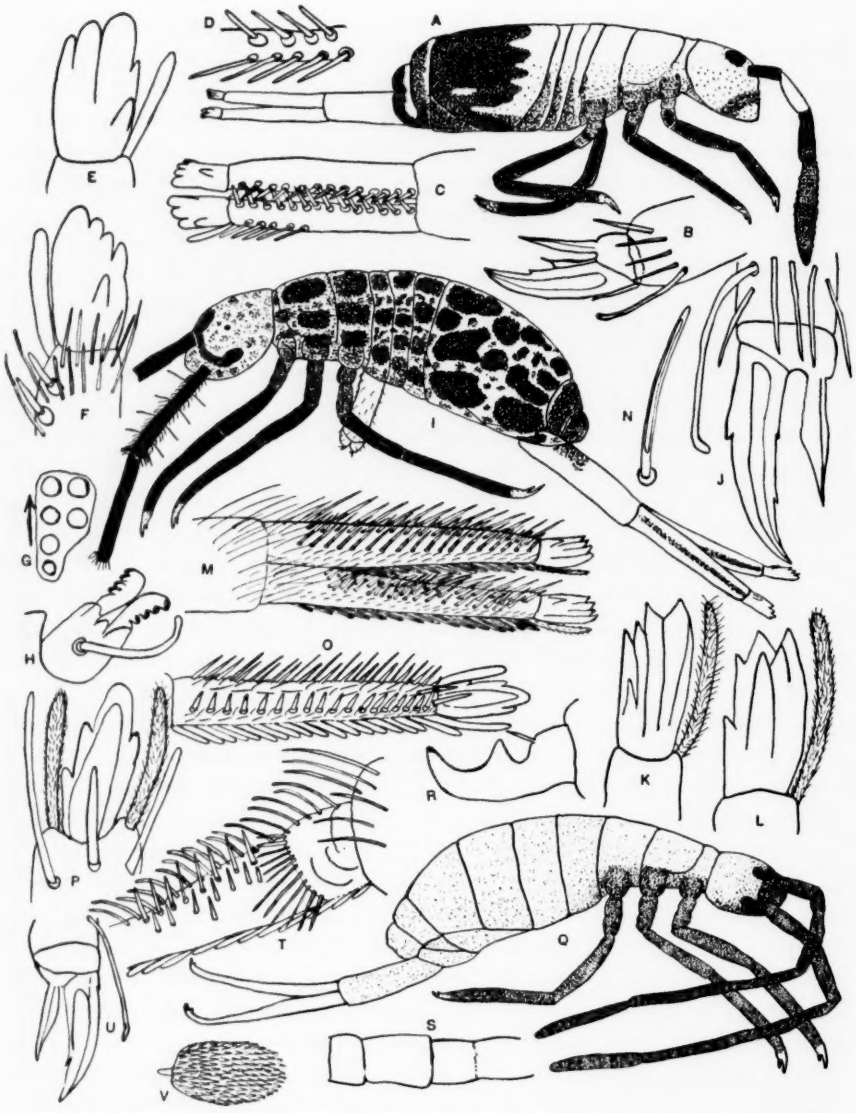

FIG. 1.—A–H, *Dicranocentrus jataca*, n.sp.: A, Whole animal; B, foot, showing unguis and unguiculus; C, dentes-mucro, showing dental spines; D, dental spines; E, mucro; F, mucro; G, eye-patch; H, tenaculum. I–P, *Dicranocentropha sabana*, n.sp.: I, Whole animal; J, foot, showing unguis and unguiculus; K–L, mucro; M, dentes-mucro; N, seta from dens; O, dens with arrangement of dental spines; P, mucro. Q–V, *Dicrano-centrella marias*, n.sp.: Q, Whole animal; R, mucro; S, first four antennal joints; T, dental spine arrangement; U, foot, showing unguis and unguiculus V, scale.

Scales present. Mucro paronelloid, with four or five apical teeth, and a basal tooth. Eyes 12, 6 on each side of head in 2 parallel rows. Antennae 4-segmented, of normal length, last segment annulated.

Genotype: Dicranocentruga jataca, n. sp.

Dicranocentruga jataca, n. sp.

Length up to 1.5 mm. Background color yellow with blue pigment, chiefly along lateral margins of body (fig. 1, A). Antennae blue throughout. Traces of blue pigment on head; pigment laterally from mesothorax to abdominal segment 4. Coxae and legs blue; abdominal segment 4 blue laterally, ventrally, and a broad posterior band dorsally; abdominal segments 5 and 6 laterally blue. Furcula yellow, but spines give the dentes a brownish tinge. Antennae 4-segmented, 1½ times longer than head or in proportion of 35:20. Proportions of antennal segments as 30:40:40:60, last segment annulated. Unguis (fig. 1, B) stout, with large lateral teeth, well-developed paramedian teeth, and a pair of teeth on distal third of inner margin. Unguiculus lanceolate, two-thirds length of unguis. Eyes 12, 6 on each side of head, in 2 parallel rows (fig. 1, G). Abdominal segment 4 about six times the length of abdominal segment 3. Tenaculum rami 4-dentate, corpus with one large bent seta (fig. 1, H). Furcula long, about two-thirds as long as body, or in proportion of 45:60. Proportions of manubrium to dens to mucro as 115:100:10. Manubrium with many dorsal setae, longer near apex. Dentes with two rows of dorsal stout spines, one row situated on inner margin and the other on lateral or outer margin, about 18 or 19 in inner row, 15 or 16 in outer row; with several rows of stiff short hairs alongside rows of spines; also longer stiff setae among the spines; ventrally, dentes are thickly set with narrow long scales rounded apically. Mucro paronelloid in shape, truncate apically, with four or five apical teeth and a large subbasal one; the number of teeth varies from three apical and one basal to five apical and one basal. Apex of dens with long large fringed setae or processes originating near base of mucro.

Superficially, the body fascies appear very similar to those of any *Entomobrya*, but for the long paronelloid furcula which places it in the subfamily *Paronellinae*. This genus is very near the genus *Trichorypha* Schött (1893), in that *Dicranocentruga* has the manubrium longer than dentes, 12 eyes are present, the mucro is similar, and the unguis has well-developed paramedian teeth. It differs from *Trichorypha*, however, in the length of antennae, the unguiculus is unarmed, and the scalelike lobe at the apex of the dens is absent. It is very near *Dicranocentroides*.

Type locality: Quebradillas, Guajataca, P.R. Taken July 4, 1951 by J. Maldonado Capriles; also by the same in Maricao, August 28, 1951.

Genus *Dicranocentroides* Imms, 1912

This genus similar to the one above is also placed in the subfamily *Paronellinae* Börner (1906) of the family *Entomobryidae*.

Genotype: Dicranocentroides fasciculatus Imms, Proc. Zool. Soc. London, Mch. 1912.

Subgenus **Dicranocentroides** (*Dicranocentroides*) s. str.

Paronelloid in general appearance. Scales present. Mesonotum not prominent. Antennae long, about half as long as the body; 4-segmented, with first segment well-developed and as long as the second. Fourth abdominal segment long, about half as long as body. Furcula long, diminishing in diameter but little throughout its entire length. Dentes with a longitudinal row of short stout spines. Mucrones with two large terminal teeth, two dorsal, subapical, and a large lateral tooth. Eyes 16, 8 on each side of head. Postantennal organ absent.

Subgenotype: Dicranocentroides fasciculatus Imms, 1912.

Subgenus **Dicranocentropha** new

Subgenotype: Dicranocentropha sabana, n. sp.

This subgenus is represented in the Puerto Rican material by one species which varies somewhat from Imms' typical form, *Dicranocentroides* (*Dicranocentroides*) s. str. I have therefore erected a new subgenus, since it is so closely related to the above. It is paronelloid in general fascies. Scales present. Antennae long, much longer than for Imms' form, the first joint being alone longer than the head, the second and third about equal to first, the fourth a little longer than the others, total length of antennae as long as or slightly longer than body. The furcula is nearly as long as the body, legs about as long as furcula, and there are several longitudinal rows of stout spines on dentes instead of one as given by Imms for his *D. fasciculatus*, 1912.

Dicranocentropha sabana, n. sp.

Length up to 2.25 mm. Yellow background color on which is dispersed bluish-purple pigment in the form of splotches, spots, and bands over head and body (fig. 1, I). Antennae and legs deep purple with pigment solidly distributed. Head with purplish pigment sparsely distributed in specks and spots; a dark line runs between eyespots along bases of antennae; a small dark spot in vertex. Eyespots dark. Ventral tube yellow. Base of manubrium with a splotch of purplish pigment and with a line of purple along middle of dentes. A broken band across dorsum, and a large splotch posteriorly and laterally on abdominal segment 4; pigment laterally along head and body, abdominal segments 5 and 6 with splotches

of pigment. Paronelloid in general appearance. Fourth abdominal segment long or about 4½ times as long as the third, or as 45:10. Antennae long or about as long as body, first segment slightly longer than head, or as 45:35; first three segments about equal, fourth slightly longer than the others. Eyes, eight on each side on dark patches. Postantennal organ absent. Legs very long, the third pair reaching to end of abdomen; the tibiotarsi, very long or as long as manubrium. Unguis (fig. 1, J) with lateral teeth and two teeth on inner margin, one a third from the base, the other a third from the apex. Unguiculus lanceolate, acuminate, two-thirds the length of the unguis. Tenent hair one on each foot, subequal in length to unguis, unknobbed. Ventral tube long, apical vesicles bilobed. Furcula very long, reaching to metathorax. Proportions of manubrium to dentes to mucrones as 40:50:4. Dentes taper but little from base to apex. Dentes with several rows of short and long heavy spines and with short stiff hairs (fig. 1, O). Ventrally with close set long scales. Mucro, suboblong, with four apical and two subapical teeth and a basal tooth. Body with short and long hairs, and with scales. Antennae with short and long hairs. Legs heavily clothed with thickly set hairs.

Type locality: Quebradillas, Guajataca, P.R., July 4, 1951, J. Maldonado Capriles; also by the same in Maricao, August 28, 1951.

Genus *Lepidocyrtus* Bourlet, 1839

Lepidocyrtus caprilesi, n.sp.

Length up to 1 mm. Background color yellowish-white, the heavy layer of scales gives the body and head a deep brownish tinge wherever thickest. A deep purple marginal line along ventrolateral edge of mesothorax just above coxae and another purple marginal line along lower edge of mesonotum; these lines are interrupted and form large purple splotches in the same position on metathorax (fig. 2, A). A few small purple spots laterally on first three abdominal segments. Abdominal segment 4 with two large patches of purple on anterior margin and two about on the middle of lateral margin; both of these in same position as those on metathorax. Head with black eyespots, a midspot on vertex, and traces of purple laterally and on bases of antennae. Antennae with traces of purple and a purple band distally on the second segment. Legs yellow except for weak traces of pigment, becoming heavier on tibiotarsi. Venter of body and furcula yellow. Antennae much longer than head, antennal segments 1 and 2 about equal in length, and combined, as long as the head. Apical end of antennal segments with a thickly set, straight row of setae (fig. 2, E–F). Eyes eight on each side. Body heavily clothed with deep brownish scales, which are rounded apically, heavily ribbed (fig. 2, B). Unguis (fig. 2, C) with two outer teeth and two pairs of inner teeth. Unguiculus

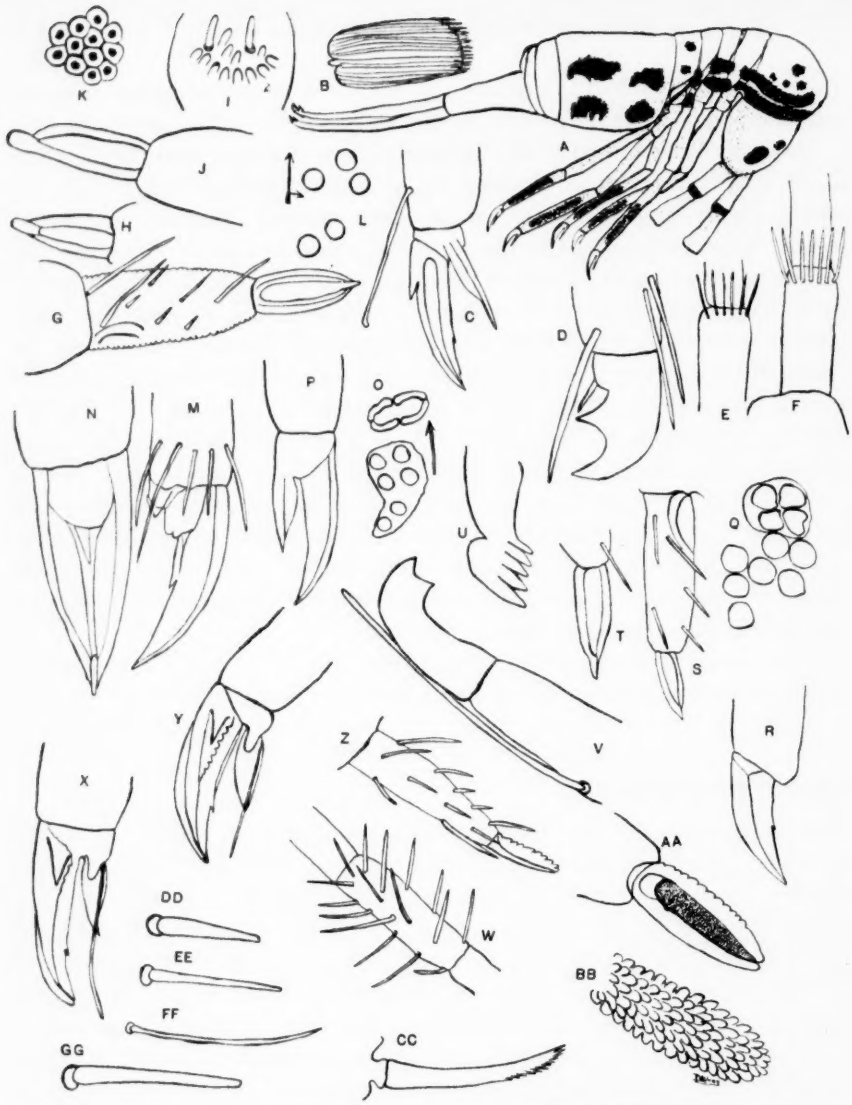

FIG. 2.—A–F, *Lepidocyrtus caprilesi*, n.sp.: A, Whole animal; B, scale; C, foot, showing arrangement of unguis and unguiculus; D, mucro. E–F, setae arrangement on antennal joint. G–N, *Portachorutes mambatus*, n.sp.: G, Dens-mucro; H, mucro; I, organ of third antennal segment; J, mucro; K, integument; L, eyes. M–N, views of unguis. O–P, *Folsomia sylvia*, n.sp.: O, Eyes and postantennal organ; P, foot. Q–U, *Brachystomella agrosa*, n.sp.: Q, Eyes and postantennal organ, R, foot; S, dens-mucro; T, mucro; U, apex of maxilla. V, *Pseudosinella subfusa*, n.sp., mucro. W–GG, *Sphyrotheca aleta*, n.sp.: W, Setae of third antennal segment; X, front foot; Y, hind foot; Z, dens-mucro; AA, mucro; BB, ventral tube apex; CC, anal appendage; DD, form of setae between eyes and back of head; EE, form of blunt setae on dorsum of abdomen and posterior of head; FF, form of setae on body; GG, form of large blunt setae on body.

lanceolate, acuminate, untoothed, about four-fifths as long as the unguis. Tenent hair subequal to unguis. Mesonotum strongly projecting over head. Fourth abdominal segment five to six times as long as third. Furcula extends as far as ventral tube. Dorsal crenulations of dens extend to about 3 mucro-lengths from end of dens. Mucro (fig. 2, D) rather long, with apical and anteapical teeth equal in size, basal spine present, stout. Body clothed with rather long closely appressed and reclinate setae especially thick on antennae, legs, and posterior of body.

Type locality: Las Marias, P.R., 5 km. from town, 500-foot elevation, August 21, 1951, in litter, collected by J. Maldonado Capriles.

Genus **Portachorutes** new

Genotype: Portachorutes mambatus, n. sp.

This genus is closely related to *Pseudachorutes* in general body fascies, but differs in that the postantennal organ is absent and the eyes number five. Antennae, 4-segmented, subequal to head in length. Furcula short, but with well-developed dentes and mucro. Unguis present, unguiculus absent or tuberculate. Body integument reticulate. Pigment dispersed in nucleated specks over body.

Portachorutes mambatus, n. sp.

Length up to 2 mm. Background color yellow with purple pigment dispersed over the body in the form of nucleated specks (fig. 2, K). Venter more lightly pigmented. Pigment on dentes and manubrium, with traces of purple on coxae, precoxae, and femorae. Antennae subequal to head in length; proportions of segments as 25:25:25:30. Organ of third antennal segment consists of several sense rods in a field (fig. 2, I). Several large sensory setae on fourth antennal segment. Eyes five on each side of head (fig. 2, L). Postantennal organ absent. Unguis (fig. 2, M–N) curved, stout, and with a weak inner tooth which may be absent on some feet. Unguiculus absent, represented by a mere tuberculation. Tenent hairs absent. Ends of tibiotarsi striated. Rami of tenaculum tridentate. Furcula short, about as long as hind tibiotarsus and unguis combined. Proportions of manubrium to dentes to mucro as 20:25:13. Dens with two long basal, dorsal setae and five or six shorter setae dorsally (fig. 2, G). Mucro (fig. 2, H) with dorsal lamellae ending before apex of mucro. Apex of mucro bluntly rounded and nearly straight.

Type locality: Las Marias, P.R. This form was taken from litter 5 km. from town, at 500-foot elevation, August 21, 1951, by J. Maldonado Capriles.

This form superficially resembles *Pseudachorutes* in general structures, but I can find only five eyes on each side and the postantennal organ is

absent. The organ of the third antennal segment is different from that of closely related forms.

Genus *Isotoma* Bourlet, 1839

Isotoma minor Schäffer, 1896

One specimen of this easily recognized species was taken at Maricao, P.R., August 28, 1951, on Road 27, 400-foot elevation, by J. Maldonado Capriles.

Genus *Folsomia* Willem, 1902

Folsomia sylvia, n. sp.

Length up to 1 mm. Color white, except for bluish pigment laterally on thorax, traces on coxae, and femorae, and slightly on antennae. Head more heavily bluish, with pigment dispersed in specks and splotches all over; eyespots heavily purplish and with pigment between these and antennal bases. Eyes 12, 6 on each side (fig. 2, O). Antennae subequal to head in length, proportions of segments as 8:10:12:25, fourth antennal segment with terminal knob; organ of third segment consists of two small sense rods. Postantennal organ broadly elliptical, notched in middle on both sides, 3 to 4 times diameter of eye in length (fig. 2, O). Unguis (fig. 2, P) curved, unarmed; unguiculus unarmed, acuminate, half the unguis in length. Furcula short, reaching only to posterior edge of abdominal segment 3; dentes twice as long as manubrium, mucro 2-toothed. Rami of tenaculum 4-dentate, corpus with one stout seta. Tenent hairs absent. Body clothed with numerous short stiff hairs and among these are many longer, stouter, setae on posterior of body.

This species is distinguished from North American species by the shape of the post-antennal organ and number of eyes.

Type locality: Las Marias, P.R., 5 km. from town, 500-foot elevation, August 21, 1951, taken in litter by J. Maldonado Capriles.

Genus *Brachystomella* Ågren, 1903

Brachystomella agrosa, n. sp.

Length up to 1 mm. Yellow background color over which purple pigment is dispersed in splotches and spots, (somewhat marbled), over head, antennae, and body. Legs more lightly pigmented. Eyes (fig. 2, Q) eight on each side on black spots. Postantennal organ of four tubercles which are almost as large as adjacent eye. Antennae shorter than head; the fourth segment with several olfactory setae and a trilobed terminal sense club. Mandibles absent. Maxillae have five or six terminal teeth (fig. 2, U). Unguis (fig. 2, R) short, stout, and with one inner tooth. Tenent hairs

absent. Rami of tenaculum tridentate. Mucrones (fig. 2, S, T) one-third of dentes in length, boat-shaped, ending in an upturned blunt apex. Anal horns absent. Clothing consisting of sparse slender, long, curved setae dispersed over head and body. Antennae thickly set with long slender setae.

Type locality: Guanica, P.R., November 20, 1951, in litter, collected by J. Maldonado Capriles.

Genus *Pseudosinella* Schäffer, 1897

Pseudosinella subfusa, n. sp.

Length up to 0.8 mm. Yellowish-white background with blue pigment diffused all over head and body in the form of small specks. Eyes two on each side of head on a small irregularly shaped dark patch. Antennae slightly longer than head. The fourth abdominal segment about two times the length of the third. Unguis has a pair of lateral teeth, a pair of prominent paramedian teeth which are not opposite, and only one inner tooth discernable. Unguiculus, straight, lanceolate, about two-thirds the length of the unguis. Tenent hair reduced, minute, short. Dentes 1½ times the manubrium in length. Dentes and manubrium have scales ventrally and many long curved hairs dorsally. Mucro, (fig. 2, V) slender, upcurved, with two apical teeth of equal size but not as deeply cleft as usual in this genus; a basal spine was not observed, but a long seta was present which originated on apical third of dens and extended beyond apex of mucro.

This species is close to *P. alba* Packard in possessing only two eyes on each side of the head, but its color, shape of mucro, and smaller size distinguish it from that species.

Type locality: Maricao, P.R., August 28, 1951, taken on Road 27, at 400-foot altitude, by J. Maldonado Capriles.

Genus *Sphyrotheca* Börner, 1906

Sphyrotheca aleta, n. sp.

Length up to 1 mm. General coloration consists of purple pigment diffused over a yellowish background over entire body. Antennae purple throughout, head and body splotched and marbled with purple, but with lighter areas showing through, legs purple throughout down to claws, manubrium and dentes with purplish pigment, and mucro purple in central part. Eyes eight on each side, on black eyespots. Ventral tube strongly tuberculate (fig. 2, BB), unpigmented, Antennae longer than head, or as 185:95; proportions of segments as 15:25:45:100. Fourth antennal segment subdivided with eight subsegments, besides basal and apical joints, and about 10 whorls of hairs. Long setae of third segment not con-

fined to one end, but distributed throughout (fig. 2, W). Unguis (fig. 2, X) with a tunica and with one tooth on inner margin one-third the distance from apex, weakly pseudonchiate at base, with lateral teeth and an outer tooth. Unguiculus broadly lamellate, with one inner tooth, and terminating in a spinnate filament which extends beyond apex of unguis on front feet, but is only subequal in length to unguis on last two pairs of legs (fig. 2, Y). Proportions of manubrium to dentes to mucro as 37:62:18. Dentes with several dorsal setae, some much longer, outstanding (fig. 2, Z). Mucro (fig. 2, AA) spoon-shaped, with crenulations on inner margin, entirely smooth on outer margin. Ventral tube very long, heavily tuberculate. Clothing of long curving pointed setae, large spinelike setae truncate at apex; those between eyes being short and stubby, those on body much longer and stouter, but straight (fig. 2, DD–GG). Anal appendage (fig. 2, CC) stout, curved, ciliated apically.

Type locality: Quebradillas, Guajataca, P.R., July 4, 1951, taken by J. Maldonado Capriles.

SUMMARY

In this somewhat preliminary survey of the collembolan fauna of this region 10 additions have been made to the short list of species previously known to occur in Puerto Rico. Nine new species, two new genera, and two new subgenera are described. Three of these new forms are closely related to forms found in India and in Africa.

RESUMEN

En este reconocimiento preliminar de la fauna collenboliana de esta región, se han hecho 10 adiciones a la corta lista de especies que anteriormente se conocían en Puerto Rico. Nueve nuevas especies, dos nuevos géneros, y dos nuevos subgéneros se describen aquí. Tres de estas nuevas formas están relacionadas estrechamente con formas encontradas en India y Africa.

EMPOASCAN LEAFHOPPERS OF THE SOLANA GROUP WITH DESCRIPTIONS OF TWO NEW SPECIES

(HOMOPTERA, CICADELLIDAE)

David A. Young, Jr.[1]

INTRODUCTION

Recently, in attempting to identify a species of *Empoasca* collected from papaya, the writer had great difficulty in establishing the identity of *Empoasca dilitara* DeLong and Davidson, to which the papaya-feeding species had previously been referred. A later examination of the type of *E. dilitara* eliminated it as a possibility, but its similarity to the unknown species and to others previously examined, led to a study of this group of similar forms which heretofore have not been associated in the literature dealing with the genus *Empoasca*. The group is here designated the *solana* group.

The males of the *solana* group are characterized by the simple rounded anal hooks, the presence of large ventral abdominal apodemes (presumably present in *manda* of which only the apex of the abdomen was studied), styles that are usually concavely truncate apically and with distinct preapical teeth, and the form of the processes of the ninth segment (pygofer processes) which tend to be elongate, constricted anteapically, and with the apices abruptly narrower than the broader basal portion. All the species possess aedeagal processes. The group is primarily tropical and subtropical in the Western Hemisphere, and at least one species is common in temperate North America.

The possibility of subspeciation in this group of closely related forms has not been ignored, but in view of the incomplete knowledge of distribution and in the light of the breeding experiments with species of this genus by F. W. Poos and his coworkers, it appears advisable to treat the forms as species at this time.

Species included in the key but not described here are being treated in another publication. All the species known to fall within this group, as characterized above, are included in the key.

The terminology employed in the descriptions of the male genitalia is explained in a recent work on Typhlocybinae (1).[2]

Examination of the types of several of the species included in this study

[1] Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture, Washington, D.C.

[2] Numbers in parentheses refer to Literature Cited, p. 160.

was made possible through the kindness of D. M. DeLong of Ohio State University.

KEY TO SPECIES

1. Aedeagal processes (or the more conspicuous pair if two pairs are present), in lateral aspect with apices extending to a point less than half the length of caudal margin of aedeagal shaft.....2

   Aedeagal processes, in lateral aspect with apices extending to a point more than half the length of caudal margin of shaft.....6

2. All aedeagal processes minute, in lateral aspect superimposed on shaft throughout their length (fig. I, 1b[3])...*canavalia*, DeLong.

   One pair of aedeagal processes conspicuous in lateral aspect, not superimposed on the shaft at any point in their length.....3

3. Aedeagal shaft with dorsal extremity strongly procurved, broad, and distinctly truncate (fig. I, 2b).....*stevensi* n. sp.

   Aedeagal shaft with dorsal extremity not or very weakly procurved, acute or rounded, not truncate.....4

4. Aedeagal shaft, in lateral aspect with caudal margin elongate-rectilinear (fig. I, 3b).....*solana* DeLong.

   Aedeagal shaft in lateral aspect with caudal margin broadly convex.....5

5. Pygofer processes in broadest aspect very broadly expanded anteapically, abruptly narrowed near apex; aedeagus with two pairs of processes, one pair very inconspicuous and superimposed on shaft in lateral aspect (fig. I, 4)

   manda Davidson and DeLong.

   Pygofer processes much more gradually narrowed near apex; aedeagus with a single pair of processes (fig. I, 5)

   dilitara DeLong and Davidson.

6. Aedeagal shaft, in lateral aspect, narrowest near midlength, distinctly broader basally and apically (fig. II, 6b)

   plebeia DeLong and Davidson.

   Aedeagal shaft with least width at its apex.....7

7. Aedeagal shaft with apical portion curved through 90 degrees.....8

   Aedeagal shaft much less strongly curved in apical portion.....11

8. Aedeagus with base of preatrium elbowed, with a single pair of conspicuous processes.....9

[3] Since it would have involved considerable delay to have the illustrations re-lettered, they are being used as lettered by the author, though not in Journal style.

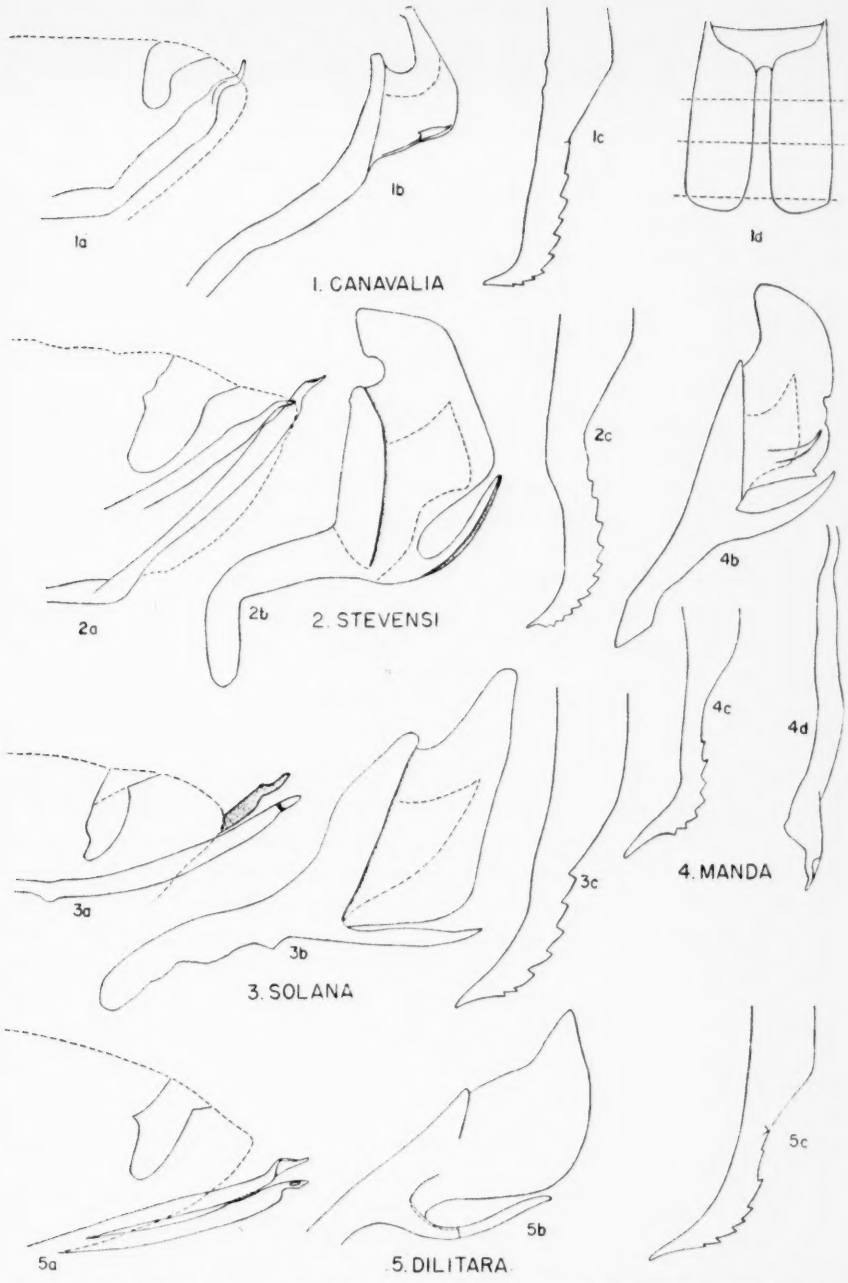

FIG. 1.—In all of the species illustrated, "a" is the pygofer in lateral aspect showing one anal hook and one pygofer process (unless two are shown); "b" is the aedeagus in lateral aspect; and "c" is a style apex. 1, *Empoasca canavalia:* d, Sternal abdominal apodemes, with broken lines representing abdominal conjunctivae. All drawings from holotype. 2, *E. stevensi:* a, From paratype, both pygofer processes shown; b and c from holotype. 3, *E. solana:* a, Both pygofer processes shown; b and c observed through wall of genital chamber. All drawings from holotype. 4, *E. manda:* d, Right pygofer process, ventral aspect. All drawings from holotype. 5, *E. dilitara:* a, Both pygofer processes shown; b, one aedeagal process broken; c, observed through wall of genital chamber. All drawings from holotype.

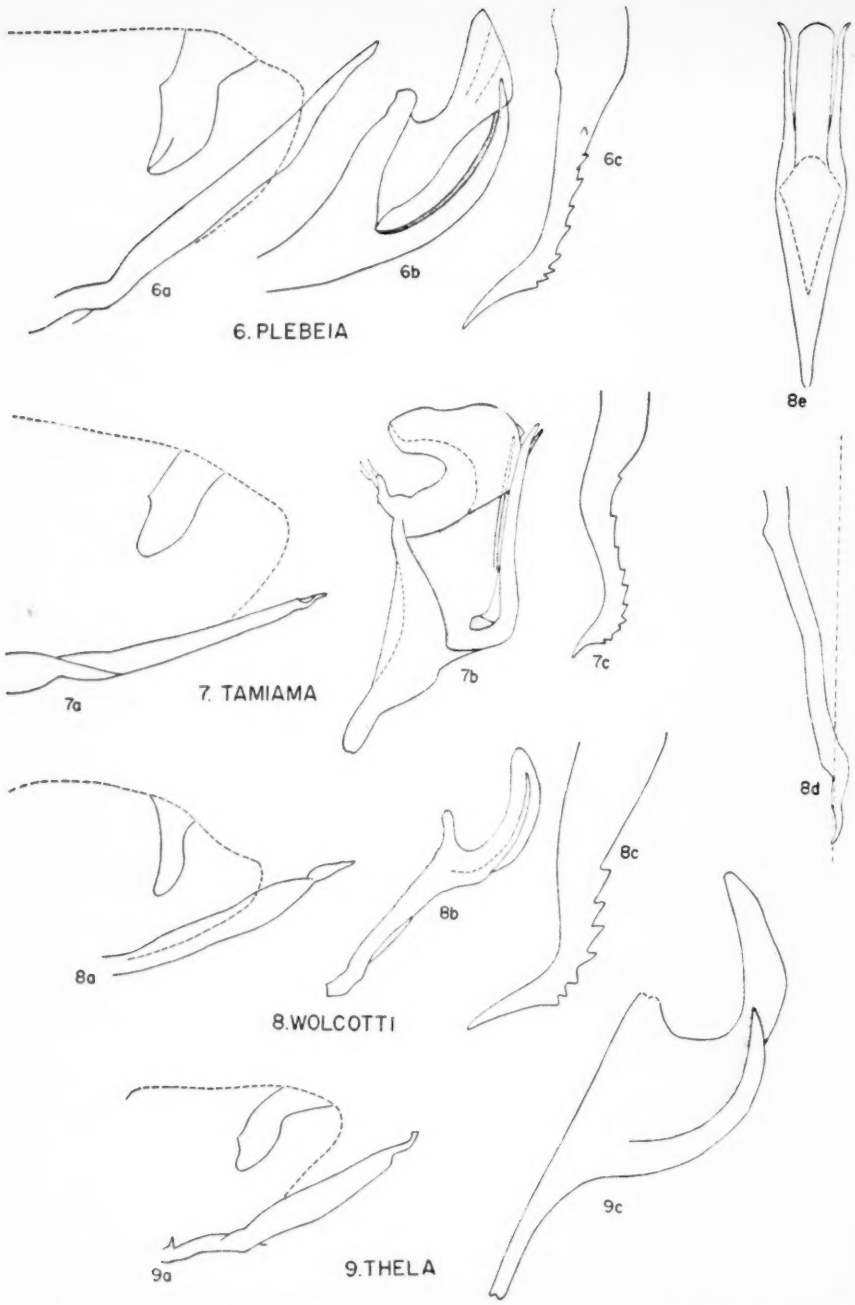

FIG. II.—In all of the species illustrated, "a" is the pygofer in lateral aspect showing one anal hook and one pygofer process; "b" is the aedeagus in lateral aspect; and "c" is a style apex. 6, *Empoasca plebeia:* All drawings from holotype. 7, *E. tamiama:* b and c Observed through wall of genital chamber. All drawings from paratype. 8, *E. wolcotti:* d, Pygofer process in ventral aspect (broken line represents midventral line of specimen); e, aedeagus in caudal aspect. Drawing a from holotype b–e from paratype. 9, *E. thela:* Both illustrations from homoeotype.

Aedeagus with preatrium straight, with a pair of large conspicuous processes and pair of small extremely slender processes (fig. II, 7b) *tamiama* Davidson and DeLong.

9. Aedeagal process in lateral aspect attaining apex of shaft *caldwelli* Davidson and DeLong

Aedeagal processes in lateral aspect with apices much basad of apex of shaft 10

10. Aedeagal processes asymmetrical, apex of style oblique *hyalina* (Osborn)

Aedeagal processes symmetrical, apex of style transverse *olivatula* Osborn

11. Pygofer processes appearing twisted apically; aedeagal processes in caudal aspect not greatly divergent from shaft (fig. II, 8) *wolcotti* n. sp.

Pygofer processes not appearing twisted apically; aedeagal processes in caudal aspect greatly divergent from shaft (fig. II, 9) *thela* Davidson and DeLong.

Empoasca canavalia DeLong

(Fig. I, 1)

This species was described from Damien, Haiti (2, 114).

Without diagnostic external specific characters. Pygofer processes convergent in ventral aspect, appearing jointed anteapically as result of abrupt dorsal curvature, apices sharp and strongly convergent but not contiguous; in lateral aspect, processes slightly exceeding posterodorsal pygofer margin, each process elbowed at base, of fairly uniform width to slightly broader apical portion, apical portion bisinuate and gradually narrowed, the extreme tip acute and directed dorsad. Aedeagus with preatrium greatly elongate and gradually curved posterodorsad; atrial border strong; shaft short, laterally compressed, curved through 90 degrees, with pair of short, acute, inconspicuous appressed lateral processes, these appearing superimposed on shaft in lateral aspect.

Holotype male in collection of D. M. DeLong. Above description based on holotype.

Empoasca stevensi n. sp.

(Fig. I, 2)

A yellowish-green species, closely related to *dilitara* DeLong and Davidson, but without external diagnostic specific characters. Length of male approximately 2.8 mm., of female approximately 2.9 mm.

Style apex and anal hook as described for the species group. Pygofer processes as in *dilitara*. Aedeagus laterally compressed; preatrium well-

developed, distinctly elbowed; atrial border strong; shaft curved through 90 degrees in apical half, the apex procurved and truncate, caudal margin rectilinear; a pair of ventral atrial processes extending beneath base of shaft, nowhere superimposed on shaft in lateral aspect; in ventral aspect, the aedeagal processes very slightly divergent apically.

Holotype male, allotype female, taken on papaya in Orlando, Fla., March 1940, by H. E. Stevens for whom the species is named (U. S. N. M. Cat. No. 61596) and 12 paratypes, same data, in U. S. National Museum collection.

Empoasca solana DeLong

(Fig. I, 3)

Originally described from Louisiana (3, p. 50).

Without diagnostic external specific characters. Pygofer processes convergent posteriorly, crossing midventral line or not, elongate, exceeding apex of pygofer, each gradually tapering from near midlength distad, abruptly narrower and arcuate at apex; in one aspect apex very similar to that illustrated for *thela* Davidson and DeLong. Aedeagus laterally compressed; preatrium well-developed; atrial border strong, giving off a pair of ventral appressed processes which, in lateral aspect, are gradually tapered in their apical halves to acute apices, and nowhere superimposed on aedeagal shaft; shaft extremely broad with a prominent dorsal apical lobe which is not procurved; caudal margin elongate, subrectilinear.

This species appears to have a wide neotropical distribution and extends well into temperate North America. The holotype male, from Baton Rouge, is in the U. S. National Museum collection. The above description is based on the holotype.

The irregular ventral margin of the aedeagal preatrium which occurs in the holotype, apparently represents an individual variation, and was not present in any of a number of other specimens examined.

Empoasca manda Davidson and DeLong

(Fig. I, 4)

Originally described from Florida (4, p. 111).

Closely related to *tamiama* Davidson and DeLong in structure of male genitalia. Without diagnostic external specific characters. Pygofer processes in broadest (near-ventral) aspect gradually widened from base to near apex, greatly widened anteapically, thence abruptly narrowed on outer margin to slender apical process which is differentially sclerotized in such a manner that the more heavily sclerotized portion is extremely slender and undulate. Aedeagus laterally compressed; preatrium well-developed, almost straight, very slightly curved at base; atrial border strong; in lateral aspect a pair of processes arising near apex of preatrium and ex-

tending in a smooth curve posterodorsad, gradually narrowed from their bases to apices, apices not attaining midlength of posterior margin of aedeagal shaft; in caudal aspect these processes appressed basally, slightly divergent apically; shaft very broad, extending dorsad, the apex slightly procurved, the posterior margin broadly convex (erose in dissected holotype), with a pair of very inconspicuous shaft processes arising near base and extending posterodorsad in a smooth curve, these processes appressed to shaft and indistinct in caudal aspect.

The male holotype, Dade County, Fla., is in the DeLong collection. Because the holotype had been dissected before examination by the writer, the pygofer processes and anal hook were not illustrated *in situ*. The sternal apodemes were not included in the preparation of the holotype. Judging from the appearance of the posterior margin of the aedeagal shaft, the erose condition of the holotype is probably not general in this species. As is commonly the case in *Empoasca* species, the dissected male genitalia offer sufficient characters for ready identification, and the lack of an illustration of the genital capsule with the parts *in situ* probably will not be a handicap.

Empoasca dilitara DeLong and Davidson

(Fig. I, 5)

This species was described from Eddy County, N. Mex. (5, p. 36).

Without diagnostic external specific characters. Pygofer processes convergent posteriorly, crossed apically, in lateral aspect, each process abruptly narrowed apically by preapical convergence of ventral margin, with extreme tip obliquely truncate and with an apparent anteapical minute areolet; in ventral aspect, processes gradually widened on apical halves, each with outer margin convergent to inner margin to form acute tip. Aedeagus laterally compressed; preatrium well-developed, straight; atrial border weak; shaft broad in lateral aspect, directed dorsad, scarcely procurved apically, caudal margin broadly convex; with a pair of slender short atrial processes extending dorsad for less than half length of shaft, slightly divergent posteriorly in ventral aspect; in lateral aspect nowhere superimposed on shaft.

The holotype male is in the collection of D. M. DeLong. The above description is based on the holotype.

Empoasca plebeia DeLong and Davidson

(Fig. II, 6)

This species was originally described from Belle Glade, Fla. (5, p. 34).

Without diagnostic external specific characters. Pygofer processes gradually convergent throughout their length, their extreme tips approximate

or contiguous; in lateral aspect, processes very long, exceeding apex of pygofer, each process gradually expanded on ventral margin beyond midlength, ventral margin thence gradually and somewhat irregularly convergent to dorsal margin, the apex not abruptly narrowed. Aedeagus laterally compressed; preatrium well-developed, straight; atrial border strong, in lateral aspect a pair of processes arising just ventrad of base of shaft, these elongate, arcuate, superimposed on shaft only at their apices which intersect ventral shaft margin but fail to attain caudal shaft margin; shaft not arcuate, directed posterodorsad, conspicuously narrower at midlength than at base or apex; in caudal aspect, aedeagal processes approximate and subparallel almost to their apices which are gradually divergent.

The holotype male, is in the collection of D. M. DeLong. The above description is based on the holotype.

Empoasca tamiama Davidson and DeLong

(Fig. II, 7)

This species was described originally from the Tamiami Trail, Fla. (4, p. 117), and redescribed as *Empoasca eweraformis* (6, p. 121) by Caldwell (new synonymy).

Without diagnostic external specific characters. Pygofer processes slightly convergent posteriorly in ventral aspect, but not crossing midventral line; in lateral aspect each process gradually tapered to preapical portion, short apical portion much narrower, its ventral margin broadly convex, the adjacent dorsal margin presenting the appearance of a small areolet, the extreme tip acute; in ventral aspect each process strongly concave at apex. Aedeagus laterally compressed; preatrium extremely short; atrial border strong; shaft curved through 90 degrees in apical half, giving off one pair of conspicuous appressed processes fused at their bases, extending along caudal margin of shaft through apical portions of their lengths, and a second pair of inconspicuous elongate slender straight processes near midlength, these not attaining dorsal margin of shaft, and with their apical halves apparently overlaid by an oblique hoodlike expansion of the dorsal portion of the shaft.

The male holotype is presumably in the collection of D. M. DeLong. The above description is based on a male paratype.

The holotype of *eweraformis* Caldwell has been studied. The new synonymy extends the range of *tamiama* to Puerto Rico. Previously it has been reported only from Florida.

Empoasca wolcotti n. sp.

(Fig. II, 8)

A yellowish species with a well-produced head, but without diagnostic external specific characters. Pygofer processes gradually approximate

throughout their lengths, their apical portions narrower, bisinuate, and crossed or superimposed in ventral aspect; in lateral aspect, processes elongate, each considerably exceeding apex of pygofer, broader on basal portion, appearing somewhat constricted and twisted anteapically, the portion distad of the constriction gradually tapered. Aedeagus laterally compressed; preatrium elongate, slightly elbowed basally, the posterior face concave; shaft smoothly curved, of uniform width throughout most its length, the apex smoothly rounded and directed cephalad; with a pair of processes arising at or near the atrial border, and extending distad in a curve nearly approximating curvature of shaft, not attaining apex of shaft, superimposed on shaft in lateral aspect, slightly divergent from shaft in caudal aspect. Style apex and anal hook characteristic of the species group.

Holotype male, allotype female, and a long series of paratypes of both sexes, Corozal, Puerto Rico, March 17, 1951 and March 20, 1951, collected "on wild pumpkin" by Julio Bird (U. S. N. M. Cat. No. 61597), in United States National Museum collection.

In addition to the above series, one specimen has been examined which was collected from cotton on March 29, 1952, also by Bird. This species is dedicated to G. N. Wolcott, whose persevering work has contributed greatly to our knowledge of Puerto Rican Homoptera.

Empoasca thela Davidson and DeLong

(Fig. II, 9)

This species was described originally (4, p. 113) from Brownsville, Texas.

Without diagnostic external specific characters. Pygofer processes not crossing midventral line, in ventral aspect each process gradually tapered, the short apical portion arched and the pair of arches parentheseslike in form; in lateral aspect, each process elongate, considerably exceeding apex of pygofer, gradually broadened from base to midlength, thence gradually narrowed to apex which is abruptly narrowed by convergence of ventral margin, upcurved, and truncate at extreme tip. Aedeagus laterally compressed; preatrium short, shaft smoothly but strongly curved dorsad, much narrower than in *solana*, with a pair of arched ventral processes arising near base, appearing superimposed on shaft throughout their length in lateral aspect, their apices acute; in caudal aspect, aedeagal processes greatly divergent from shaft; shaft slightly narrowed at midlength, but not conspicuously constricted as in *plebeia*.

The male holotype presumably is in the collection of D. M. DeLong. The above description is based on a male homoeotype.

SUMMARY

Difficulty in establishing the identity of a species of *Empoasca* collected on papaya led to a study of a primarily neotropical group of species related

to *Empoasca solana*. The group includes *canavalia, solana, manda, dilitara, plebeia, tamiama, caldwelli, hyalina, olivatula, thela,* and two new species: *stevensi* and *wolcotti*. A key to the 12 species, and descriptions of 9 of them are included.

RESUMEN

La dificultad existente para identificar una especie de *Empoasca*, colectada en el árbol de papaya, motivó un estudio sobre un grupo neotropical de especies afines a la *Empoasca solana*. El grupo incluye las especies *canavalia, solana, manda, dilitara, plebeia, tamiama, caldwelli, hyalina, olivatula, thela,* y dos nuevas especies: *stevensi* y *wolcotti*. Se incluye una clave para identificar 12 especies y se describen 9 de éllas.

LITERATURE CITED

1. Young, D. A., A reclassification of Western Hemisphere Typhlocybinae, *Univ. Kans. Sci. Bull.* **35** 1–217, 1952.
2. DeLong, D. M., Three species of *Empoasca* leafhoppers known to affect economic plants in Haiti, *J. Dept. Agr. P. R.* **16** 113–15, 1932.
3. DeLong, D. M., A revision of the American species of *Empoasca* known to occur North of Mexico, *U. S. D. A. Tech. Bul.* **231** 1–59, 1933.
4. Davidson, R. H. and DeLong, D. M., Studies of the genus *Empoasca*, Pt. VI, *Ohio J. Sci.* **39** 110–18, 1939.
5. DeLong, D. M. and Davidson, R. H., Further studies of the genus *Empoasca*, Pt. III, *Ohio J. Sci.* **36** 29–39, 1935.
6. Caldwell, J. S. and Martorell, L. F., Review of the auchenorynchous Homoptera of Puerto Rico, Pt. I, Cicadellidae, *J. Agr. Univ. P. R.* **34** 1–132, 1952.

OBSERVATIONS ON THE CHROMOSOME NUMBER OF *PENNISETUM CILIARE*

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INTRODUCTION

As part of the breeding program of the Plant Breeding Department of the Agricultural Experiment Station of the University of Puerto Rico, some cytological observations have been made on different strains of "buffel grass" (*Pennisetum ciliare* (L.) Link, Hart; Berol) (4)[2]. This work constitutes a preliminary report on the chromosome number of the native and some imported buffel grass strains.

Buffel grass belongs to the tribe Paniceae, family Gramineae. In India, its place of origin, it is known as "anjan grass", while in the United States it is generally known as "buffel grass". At present this Station has under propagation 11 different introduced strains. All the grasses mentioned in this study, with the exception of our native buffel grass, were obtained from Dr. E. James, Regional Plant Introduction Station, Experiment, Ga. Our native grasses were obtained from the collection of grasses at this Agricultural Experiment Station.

The Puerto Rico strain is a thin-leaved and relatively short grass found growing wild in the savanna areas and undulating lands of the southern coastal plains, especially around Salinas, Santa Isabel, and Ponce. (3)

Buffel grass is characterized as a perennial which grows from a knotted crown, the culms being geniculate, having a height of from 4 to 20 inches, though some strains may be taller. It is sparingly branched and the blades are narrow, flat, or folded with a length varying from 2 to 5 inches, or sometimes more. Seed is produced by this grass throughout the year, but the peak of the seed-bearing season is from June to September. The spikelike panicle has a length of from 1 to 4 inches, a purplish color, and is generally flexuous (4).

This grass is quite resistant to drought. Usually it is one of the last grasses found green during dry seasons and one of the first to start growing after long periods of dry weather. Since it is very palatable, it is widely preferred by grazing animals.

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[2] Numbers in parentheses refer to Literature Cited, p. 170.

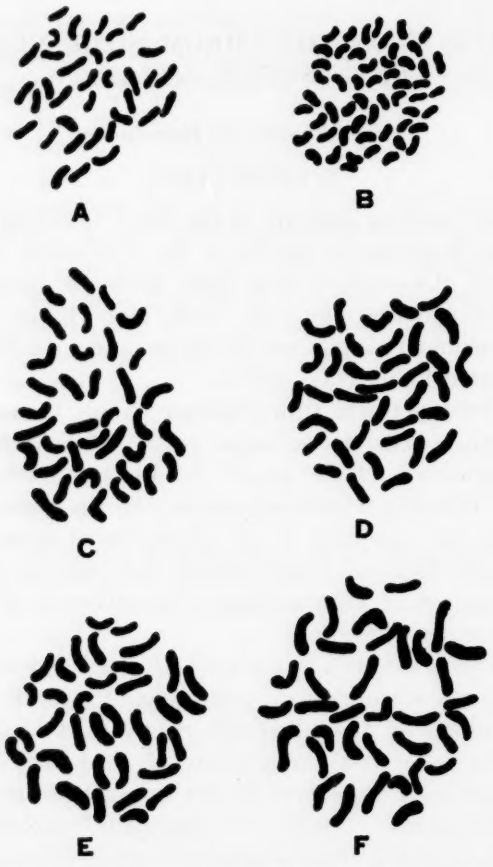

FIG. 1.—Drawings showing chromosomes of *P. ciliare* strains studied: A, Native; B, anjan grass, U.S.D.A. 164601, P.R. 204; C, anjan grass, U.S.D.A. 164414, P.R. 202; D, buffel grass, U.S.D.A. 193445, P.R. 917; E, anjan grass, U.S.D.A. 164607, P.R. 203; F, buffel grass, U.S.D.A. 185641, P.R. 918.

TABLE 1.—*The 2n chromosome numbers of each grass strain studied, along with their U.S.D.A. and their P.R. Plant Introduction Nos., and place of origin*

Strain	U.S.D.A. P.I. No.	P.R. P.I. No.	Place of origin	2n
1, native	—	—	Puerto Rico	36
2, anjan grass	164414	202	Hissar, eastern project, India	36
3, anjan grass	164607	203	Madras College, Coimbatore, India	36
4, anjan grass	164601	204	Do.	54
5, buffel grass	193445	917	Western Australia	36
6, buffel grass	185641	918	Africa	36

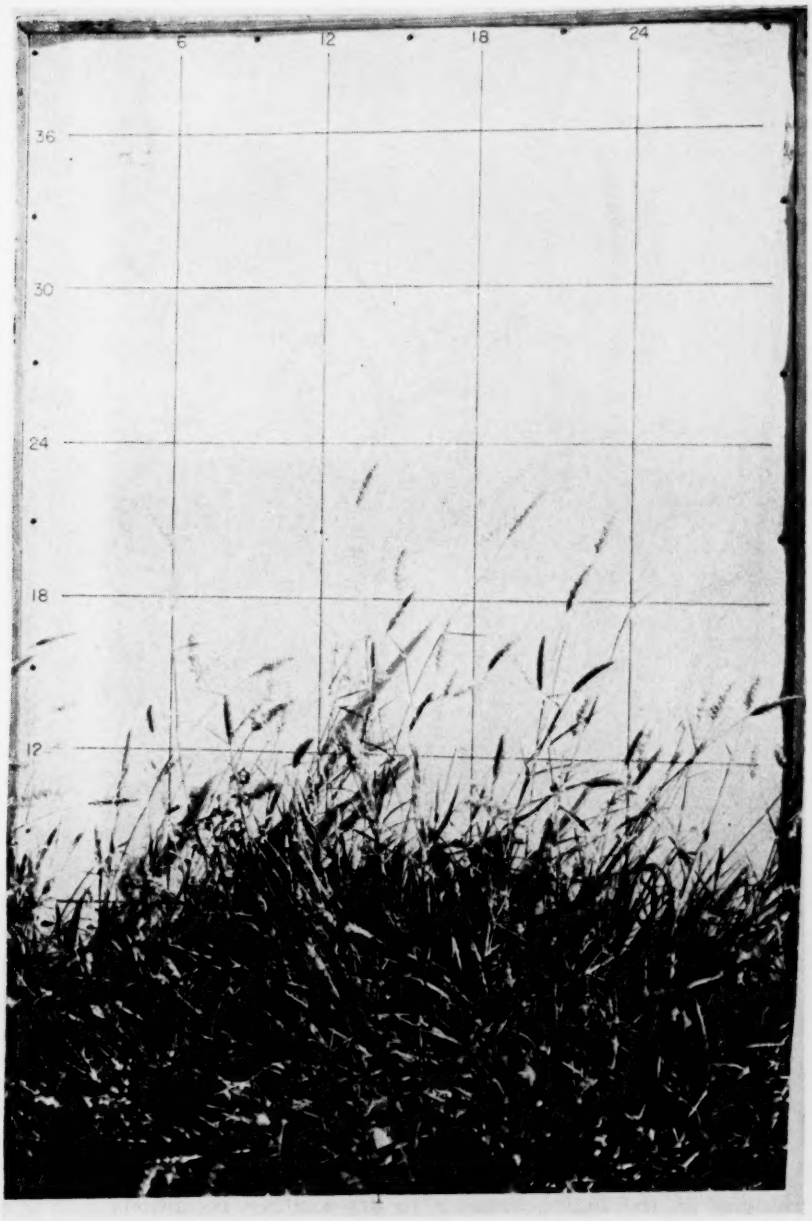

FIG. 2, A.

FIG. 2.—Appearance at 2½ months of the different strains of *P. ciliare* studied: A, Native; B, P.I. 202; C, P.I. 203; D, P.I. 204; E, P.I. 917; F, P.I. 918.

FIG. 2, B.

OBJECTIVES

Because of the high resistance to dry-weather conditions shown by buffel grass, it was considered of importance to make cytological studies of the different strains to determine the possibilities of its use in crossing with some other tall and more leafy *Pennisetum* species. The full investigation will cover the study of: Chromosome number, arrangement and rela-

FIG. 2, C.

tion, irregular separation, and lagging chromosomes, if present, so as to obtain a better view of the breeding behavior and the possible use of buffel grass in grass improvement by hybridization and selection.

So far the cytological work carried on with this grass has consisted of chromosome counts from late-prophase mitosis in somatic root-tip cells. Nevertheless, it is our purpose to make a more detailed study of the late

FIG. 2, D.

diakinesis stage of the meiotic division in pollen mother cells, which will be reported later. For such studies of meiosis young inflorescenses are fixed in absolute-acetic fixative and anthers smeared in propio- and aceto-carmine stains.

FIG. 2, E.

MATERIALS AND METHODS

Vegetative material was grown in the greenhouse for root-tip production. All material to be used was planted in 3- and 4-inch pots. In some cases seed were planted while in others cuttings or sprigs from plots of the grass collection were used. Approximately 1 month after planting was required

FIG. 2, F.

for obtaining appropriate material consisting of white, thick, round, clean root tips.

Root tips from all the grasses studied in this report were collected between 8:00 a.m. and 10:00 p.m. The fixation was done with Belling's Modified Navashin fluid, or with Randolph Modified Navashin fluid (CRAF) The material was left on the fixatives approximately 24 hours.

The root-tip material was embedded and sectioned according to the standard procedures of the paraffin method (5). Cross sections were cut from 8 to 10 microns and were stained by the Feulgen technique (5).

Chromosome counts and drawings were made with the aid of a Spencer camera lucida. The drawings were made at table level using a 30× compensating ocular and a 1.8-mm. fluorite oil immersion, objective; therefore all have the same degree of magnification (see fig. 1).

RESULTS

Table 1 lists the 2n chromosome number obtained for each strain, the original location of the grass, and the U.S. Department of Agriculture Plant Introduction No. as well as the Puerto Rico Introduction No.

TABLE 2.—*Growth habits and other vegetative details of the various strains of* P. ciliare, *studied*

No.	Strain	Growth habit	Average height	Spikes	
				Color	Approximate size
			Feet		*inches*
1	Native	Bunch, slightly decumbent	1–1½	Light brown	2
2	P.I. 202	Bunch, erect, heavy tillery	2–2½	Brownish	4
3	P.I. 203	Bunch, erect, good-quality forage	3	Light brown	5–6
4	P.I. 204	Bunch, erect	2½—3	From light brown to almost black	4–5
5	P.I. 917	do.	2–3	Brownish	4½
6	P.I. 918	Bunch, decumbent	2½	Light brown	4

Figure 1 shows a series of camara lucida drawings all of which have the same magnification. These chromosome counts were derived from different strains of species of *Pennisetum* (Penicillaria) (2) not previously reported in Darlington's Chromosome Atlas of Cultivated Plants.

Figure 2 shows the different strains of *P. ciliare* described in this work. All of them were 2½ months old when the photographs were taken. Vegetative appearance and other details are shown in table 2.

SUMMARY

Chromosome counts are given for various strains of *Pennisetum ciliare*, commonly named "buffel grass" and "anjan grass".

All strains of *P. ciliare* reported upon herein are tetraploids, with but one exception, which seems to be a hexaploid.

RESUMEN

Se ha informado en esta publicación el número de cromosomas de algunas formas de *P. ciliare*, comunmente conocida como "buffel grass" o "yerba anjan".

Se observó que todas las yerbas informadas aquí son tetraploide, con una excepción, que parece ser hexaploide.

LITERATURE CITED

1. Brown, Walter V., A Cytological study of some Texas gramineae, *Bull. Torrey Botanical Club and Torreya*, **77**(2) 1950.
2. Darlington, C. D. and Janaki Ammal, E. K., Chromosomes Atlas of Cultivated Plants, George Allen and Unwin Ltd., London, 1945.
3. García Molinari, Ovidio, Grassland and grasses of Puerto Rico, Bull. **102**. Agricultural Experiment Station, Río Piedras, P. R., August 1952.
4. Hitchcock, A. S., 1935 Manual of the grasses of the West Indies, Misc. Publ. **243**, U. S. Dept. of Agri., Washington, D. C., 1936.
5. Johansen, D. A., Plant Microtechnique, McGraw Hill Book Co., Inc., New York and London, 1940.